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A Summary of Current Program and
Preliminary Report of Progress

-

GRAIN RESEARCH

of the
United States Department of Agriculture
and cooperating agencies

This progress report of U.S.D.A. and cooperative research is primarily a tool for use of scientists and administrators in program coordination, development and evaluation; and for use of advisory committees in program review and development of recommendations for future research programs.

There is included under each problem area in the report, a brief and very general statement on the nature of the research being conducted by the State Agricultural Experiment Stations and the professional manpower being devoted by the State stations to such research. Also included is a brief description of related work conducted by private organizations. No details on progress of State station or industry research are included except as such work is cooperative with U.S.D.A.

The summaries of progress on U.S.D.A. and cooperative research include some tentative results that have not been tested sufficiently to justify general release. Such findings, when adequately confirmed will be released promptly through established channels. Because of this, the report is not intended for publication and should not be referred to in literature citations. Copies are distributed only to members of Department staff, advisory committee members and others having an interest in the development of public agricultural research programs.

This report also includes a list of publications reporting results of U.S.D.A. and cooperative research issued during the last two years. Current agricultural research findings are also published in the monthly U.S.D.A. publications, Agricultural Research, Agricultural Marketing, and The Farm Index.

UNITED STATES DEPARTMENT OF AGRICULTURE
Washington, D. C.
December 1, 1962

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Dairy	Tobacco
Deciduous Fruit and Tree Nut	Vegetable
Forage, Feed and Seed	Economics
Forestry	Farm Equipment and Structures
Livestock	Food and Nutrition
Oilseeds and Peanut	Food Distribution
Potato	Home Economics
Poultry	Soils, Water and Fertilizer
Rice	Transportation and Storage

Two additional reports of progress are prepared in order to make available the complete research program. They are:

Ornamentals and Other Miscellaneous Commodities
Other Research -- Cross Commodity

ORGANIZATIONAL UNIT REPORTS

All of the material in the commodity and functional reports listed above is the same as that found in the 20 division and 3 service research reports listed below.

Agricultural Research Service (ARS)

Agricultural Engineering
Animal Disease & Parasite
Animal Husbandry
Crops
Entomology
Soil and Water Conservation
Utilization -- Eastern
Utilization -- Northern
Utilization -- Southern
Utilization -- Western
Human Nutrition
Clothing and Housing
Consumer & Food Economics

Agricultural Marketing Service (AMS)

Market Quality
Transportation & Facilities

Economic Research Service (ERS)

Farm Economics
Marketing Economics
Economic & Statistical Analysis
Foreign Development & Trade Analysis
Foreign Regional Analysis

Other Services

Farmer Cooperative Service (FCS)
Forest Service (FS)
Statistical Reporting Service (SRS)

A copy of this report or any of the others listed above may be requested from W. C. Dachtler, Executive Secretary, Grain Research and Marketing Advisory Committee, Agricultural Research Service, U. S. Department of Agriculture, Washington 25, D. C.

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INTRODUCTION

This report deals with research on grain and grain products. It covers Farm Research, Utilization Research, Marketing Research, Economic Research and Nutrition and Consumer-Use Research of the U.S.D.A. and cooperating agencies. Only a brief description of the related work of the State Experiment Stations and industry is included.

Under each of the Problem Areas there is a statement describing the Program of work underway and the professional man-years devoted to the major kinds of research included. The relative scope of the total research effort on grain is indicated by the approximate number of professional man-years employed: About 425 by U.S.D.A., about 300 by the State Experiment Stations and about 1400 by industry and other organizations.

A brief report of Progress and significant findings for U.S.D.A. and cooperative programs is given for each phase of the research program.

A considerable amount of basic cross-commodity and functional research that will supply new knowledge applicable to grain problems is not included in this report. Such research is included in the functional reports such as "Economics," "Soils, Water and Fertilizer" and in the "Other Research" report.

RESEARCH BY USDA

The farm research comprises investigations on introduction, breeding and genetics, variety evaluation, culture, diseases, nematodes, weed control, insects, and crop handling and harvesting equipment and structures. This research is conducted by the Crops, Entomology, Agricultural Engineering, and Soil and Water Conservation Research Divisions of the Agricultural Research Service. In fiscal year 1962 this work involved about 180 professional man-years.

Utilization research deals with new and improved feed, food and industrial products and processes related to grains. The work is carried on by the Agricultural Research Services, Northern Utilization Research and Development Division, at Peoria, Illinois, and the Western Utilization Research and Development Division at Albany, California. In fiscal year 1962, this work involved about 180 professional man-years.

Market research involves the physical and biographical aspects of assembly, packaging, transporting, storing and distribution of grain and grain products from the time they leave the farm until they reach

the ultimate consumer. The work reported herein is carried on by the Market Quality and Transportation and Facilities Research Divisions of the Agricultural Marketing Service. It involved 37 professional man-years in fiscal year 1962.

Economic research is concerned with market potential; costs, margins and efficiency; market structure and practices; supply and demand; outlook and situation; consumer preference and quality discrimination; and crop estimating procedures. This work relating to grain and grain products is carried on by the Marketing Economics and the Economic and Statistical Analysis Research Divisions of the Economic Research Service; the Marketing and Management Services Divisions of the Farmer Cooperative Service; and the Standards and Research Division of the Statistical Research Service. In fiscal year 1962, 22 professional man-years were devoted to this work.

Nutrition and consumer-use research pertains to composition and nutritive value of foods; physiological availability of nutrients and their effects; and new and improved methods of preparation, preservation and care in homes, eating establishments and institutions. This work is done by the Human Nutrition and the Consumer and Food Economics Research Divisions of the Agricultural Research Service. It involved 9 professional man-years in fiscal year 1962.

RESEARCH BY STATE EXPERIMENT STATIONS

There is included under each problem area a brief and very general statement on the nature of the research being conducted by the State agricultural experiment stations and the professional man-power being devoted by the State stations to such research.

Consolidating this information for the entire field of interest, we find that in fiscal year 1962 about 300 professional man-years were spent by the State agricultural experiment stations on grain and grain products research.

Grain and grain products research in 1962 was in progress in 42 of the 53 State agricultural experiment stations. Studies under way were carried out by research workers in the departments of agronomy, agricultural economics, agricultural engineering, entomology, food technology, home economics, and plant pathology.

Grain and grain products research at the agricultural experiment stations in 1962 included 10 man-years on the agricultural engineering phases of crop harvesting operations, equipment, crop preparation, farm processing, storage buildings, and electromagnetic equipment to control insects.

The largest segment of work at the State experiment stations might be classified under crops. In culture, breeding, diseases, and variety

evaluation research 26 man-years were devoted to barley, 105 man-years to corn and sorghum, 58 to wheat and rye, and 30 man-years to oats. In addition, a considerable amount of related research was conducted on problems which could not be readily identified with respect to specific commodities. This research included work on weed control, nematode identification, physiology and control, and crop introduction and evaluation.

Entomology research included 27 man-years on control of grain insects.

Several lines of research and development concerned with utilization are under way at the State experiment stations. Industrial utilization research included 15 man-years on cereal starches, wheat, and high amylose corn. Research pertaining to fermentive conversion of new wheat and corn industrial feed and food products and research dealing with wheat, barley, corn, and sorghum food and feed products and processing accounted for 9 man-years.

The State experiment stations devoted 4 man-years to human nutrition and consumer research on grain and grain products. In addition, closely related research on market quality of grain and grain products was also conducted.

Grain marketing research at the State experiment stations included 9 man-years on the economics of transportation and storage; supply, demand, and price analysis, and marketing operations of cooperatives. In addition, a considerable amount of related research was conducted on problems which could not be readily identified with specific commodities such as grain. This research included work on market structure and practices, marketing costs, margins and efficiency, market potentials for new products and new uses, merchandising and promotion, economics of product of quality and grade, and of crop estimating procedures.

No details on progress of State station research are included in this report except as such work is cooperative with the USDA.

RESEARCH BY INDUSTRY AND OTHER ORGANIZATIONS

The 1200 to 1400 professional man-years estimated for calendar year 1961 as industry's participation in research on grain and grain products are employed primarily by seed companies, chemical and fertilizer firms, millers and other processors of feed, food, and industrial products and by equipment and facilities manufacturers. In addition, market research institutes and corporations, producer organizations, and individual farmers contribute substantially to industry's program of grain research.

The seed industry has extensive programs for the development of new grain varieties, inbred lines and the evaluation of such lines in hybrid combinations. The lines developed, however, are not released for general use and in many cases the research findings are not published.

Chemical companies are synthesizing and evaluating chemicals as herbicides and insecticides. Associated research includes fundamental toxicological research and applied studies on effective formulations, safety techniques for application and persistence of residues. Results of primary screening of chemicals by industry are frequently not published.

Fertilizer companies make a significant contribution in research on the development of new materials or combinations of materials to produce grains more efficiently through better nutrition of the growing plant.

A number of millers and other grain processors are conducting research in various phases of product and process development. The studies include a wide field usually directed toward the securing of patents. Allied industries and suppliers to the food processing industry maintain laboratories and research staffs to provide technical information. Most of this work is of a trouble-shooting nature, although valuable contributions to the store of basic knowledge have been made by this group.

Equipment and facility manufacturers also make sizeable contributions to research on the development of equipment for planting, cultivating, harvesting, handling, conditioning and storing grain and grain products during all stages from the time of land preparation through the retail outlet of the cereal product.

Market research institutes and others in marketing economics research are largely concerned with consumer preference, market potential, promotion and development studies. The results frequently are available only to the purchaser of the service.

It is very difficult to fully assess the contributions made by grain growers to the overall effort on grain research. In the field of production their help is indispensable for many of the laboratory research results must be confirmed by field scale experiments. The farmer cooperates with the USDA and State Experiment Stations by supplying the use of land, labor, materials and equipment often without compensation other than for the experience and knowledge gained.

Industry's cooperation in supporting research on grain and grain products in the form of grants, gifts or loans of materials, equipment, and facilities at Federal and State field stations has contributed greatly to its success.

No details of the progress of industry research are included in this report except as such work is cooperative with a program of USDA.

EXAMPLES OF RECENT RESEARCH ACCOMPLISHMENTS
BY USDA AND COOPERATING SCIENTISTS

"Cereal pulp" for use in paper. New wheat flour and cereal starch products have been discovered that can be economically incorporated as an integral part of paper and other pulp products. Wheat flour and starches have been converted into water-soluble chemical derivatives that can be added to slurries of paper pulp. After a simple chemical treatment, the additives are precipitated on the pulp fibers and become part of the paper sheet. No chemical used to make the cereal product costs more than 5 cents a pound. Papers have been made in laboratory experiments containing as high as 45 percent of cereal product. The papers had higher dry and wet tensile strengths than all-wood-pulp papers. No operating conditions that would conflict with commercial paper processes were necessary.

High-amylose corn starch available in commercial quantities. The Department's cooperation with industry on breeding and processing of a series of high-amylose corns has been the key factor in the commercial production of high-amylose corn starches, tailor-made especially for a variety of industrial uses. Over three million pounds of this new corn starch containing about 61 percent apparent amylose was produced commercially from the 1961 high-amylose corn crop. Production for 1962 is estimated at five million pounds. Most of this new industrial starch is used as a size in the manufacture of glass fiber products. Further opportunities lie in industrial applications such as textile size, films, fibers, and pulp and paper additives.

New bulgur process to aid wheat exports. A new, continuous process has been developed by the Agricultural Research Service for the conversion of wheat into bulgur (parboiled wheat). This process, which operates at atmospheric pressure, is economical in heat and labor requirements and employs conventional, readily-available equipment. A large midwestern grain company is constructing a bulgur plant based on this method, while other companies are converting existing equipment. Present plans of the Department call for the movement of over 300 million pounds of bulgur into school lunch and other market-building programs abroad this year.

Plant varieties resistant to insect attack. Although only limited effort has been devoted to the development of plant varieties resistant to insect attack, excellent progress has been made in dealing with several important insect problems by this desirable control method. Seventeen varieties of wheat that possess resistance to the hessian fly, a long-time serious pest of wheat, have

been developed as a result of cooperative efforts of Federal and State entomologists and plant breeders. These varieties have been released to the growers by State Experiment Stations in cooperation with the U. S. Department of Agriculture. Nine of the resistant varieties were released in 1960-62. Today hessian fly-resistant wheats are being grown on more than 4,500,000 acres of winter wheat. As a result this formerly major pest has been relegated to the status of a minor pest of wheat. Plant breeders and entomologists working together have made rapid progress in the development of varieties of alfalfa highly resistant to the spotted alfalfa aphid, an important pest accidentally introduced into the United States in 1954. After only a few years of research, four varieties--Lahontan, Moapa, Zia, and Cody--each adapted to particular areas, are now being grown in the Western States.

Protective treatments against insect-infestations. The development of insecticide coatings, the improvement of package construction and the use of laminated heat-sealed tape over stitching have effectively prevented insect invasion and penetration of flour bags for 2 years. Mothproof treatments with DDT applied to rolls of cloth during the sponging process have effectively protected the cloth exposed to heavy insect infestation for 13 years. Economical and effective treatments for grain during storage and shipment have been developed and are now in use in commercial storages, in ships storing surplus grain and in facilities used for transporting grain. These developments alone have been worth many millions of dollars per year.

Research indicates prospects of lowering marketing margins for bread. A study of the baking industry completed during the past year shows that technological improvements such as oven firing, automatic handling and continuous dough mixing make possible significant reductions in the cost of producing bread.

To fully realize such economies the volume of output per plant needs to be increased. Thus it was determined that plants producing 2,000 pounds of bread per hour with standard equipment and operating 36 hours a week might have production costs of between 11 and 12 cents per pound loaf whereas bakeries producing 8,000 pounds per hour, using improved equipment and operating 108 hours per week might expect costs of between 6 and 7 cents per pound loaf. It also was discovered that economies in distribution can be achieved with possible savings of 3 to 4 cents per pound loaf. The reality of these prospective economies is suggested by the achievements of some of the food chains which have acquired their own baking plants or have longer-term purchase commitments with particular suppliers. Some of these organizations recently have reduced retail prices of bread by as much as 5 cents per pound loaf below the U. S. average.

I. FARM RESEARCH

BARLEY CULTURE BREEDING, DISEASES AND VARIETY EVALUATION Crops Research Division, ARS

Problem. Of the cereal crops, barley ranks fifth in the United States in acreage, production, and value of the crop. During the last 10 years the acreage planted to barley has increased approximately 25 percent to over 16 million acres. Barley is grown in 49 of the 50 states and is a major crop in 40 states, representing a wide variety of environmental conditions. Half of the crop is used as feed for livestock, 20 to 30 percent for malting, and 20 percent is exported. Barley is subject to yearly fluctuations in yield and quality because it is grown so widely, due to factors such as climate, disease, lodging, winterkilling, shattering, drought injury, insect damage, and other factors. There is an increased need for work on genetics, cytology, pathology and physiology to strengthen the breeding work, for breeding barleys to buffer the effects of the hazards mentioned. Studies on the important disease organisms, including viruses, host-parasite relationships at both physiologic and genetic level, nature of disease resistance, and host range of various parasites are basic studies that need strengthening. There is an increasing need for research on malting quality, for a more precise definition of quality and methods of evaluation. For all phases of breeding, we need to find a universal way by which individual genes can be identified with complete accuracy in the parents and in their progeny. The basic new concepts emerging from studies on DNA, the genetic code, transduction and other techniques; the newer methods of chromosome engineering, and the new advances with chemical mutagens need to be thoroughly studied and investigated for their possible use in applied barley breeding. The studies on the possibility of hybrid barley need to be intensified, as well as the role of genetics in the use of agricultural chemicals. Applied studies that need greater attention include the effects of environmental factors and cultural practices on yield and quality; and on factors to reduce the yearly fluctuations in yield and quality.

USDA PROGRAM

The Department has a continuing long-range program on barley improvement. Both basic and applied research is being used. In basic research the areas under investigation are genetics, cytogenetics, radiation genetics, pathology, virology, biochemistry, and physiology.

Basic and/or applied research is carried on in cooperation with the following State Agricultural Experiment Stations: Arizona, California, Idaho, Michigan, Minnesota, Montana, Nebraska, North Carolina, North Dakota, South Dakota, Utah, and Wisconsin. A Federal National Barley and Malt Laboratory is located at Madison, Wisconsin, and is operated in cooperation with the Wisconsin Agricultural Experiment Station. This laboratory conducts the quality work on barley for both State and Federal programs. The world barley collection is maintained and distributed from Beltsville, Maryland. Federal personnel supervise 4 spring and 3 winter uniform nurseries.

The Federal scientific effort devoted to research on barley totals 18.2 professional man-years, of which 8.1 is for breeding and genetics, 4.0 for diseases, 5.0 for variety quality evaluation, and 1.1 for culture (physiology).

Additional research on barley is carried out under five Public Law 480 projects located in three foreign countries, namely: Poland (2), Egypt (1), and Israel (2). This research includes studies on the diseases affecting barley, namely, rusts, smut, net blotch, mildew and scald, and a search for varieties resistant to these diseases; also studies on the origin of barley. The effect of genetic and environmental factors on the feeding value of barley proteins is being studied by Montana State College under a contract involving an estimated 6 tenths professional man-year.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

For the State experiments the total man-years is 25.6 and divided in the following manner: 12.6 for breeding barley of malting quality and local adaptation, mutation breeding using chemical and ionizing agents, genetic studies and species hybridization; 5.6 man-years for disease investigations including studies on yellow dwarf, stripe mosaic, smut, spot blotch, net blotch, foot rots, mildew and scald, on fungicides, breeding for disease resistance, and cultural practices to aid in disease control; 5.3 man-years on variety evaluation, including prediction quality evaluation of barley selections from early generation hybrids; and 2.1 man-years on cultural practices including rates and dates of seeding, rotations, fertilizers and their placement, artificial drying of grain, etc.

The related work done by industry consists of supplying chemicals for cooperative tests, and in the evaluation of barley varieties for malting and brewing quality in 15 industrial laboratories. It is estimated that this effort totals approximately 8 man-years.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Breeding and Genetics

1. Hybrid Barley. At Beltsville, Maryland and Aberdeen, Idaho, important steps were taken during the year toward hybrid barley. A genetic and chemical combination, using genes for male sterility and resistance to DDT, in combination with spray applications of DDT were worked out, whereby the crossed seed needed for hybrid production could be produced mechanically. The scheme, while attractive, has not yet been proven. We lack a close genetic linkage between the genes for male sterility and DDT resistance; but from genetic theory we know that this linkage can be obtained. We also need more data on the degree of cross pollination. At Davis, California, manual crosses have shown that the yield increase from hybrid barley is on the order of 30 to 50 percent.

In the search for a natural linkage between a male sterile gene and the gene for DDT resistance, it was found that nearly every new male sterile gene discovered is located at a different locus. Of the first 9 such genes tested at Bozeman, Montana, 8 were at different loci, and 2 of these appear to be linked on one chromosome.

2. Composite Cross. At Davis, California, a world composite cross was made and distributed during the year. The use of a male sterile gene made this cross possible, and it is estimated that a total of 5,200 parents went into this cross. The composite has had world-wide distribution, and should be particularly suited to underdeveloped countries. The built-in facility (male sterility gene) will create additional recombinants through outcrossing, and this, combined with natural selection at the locality where grown, will provide a pool of adapted genotypes from which selections can be made in a later generation for testing and evaluation.

3. Cytogenetics. At Tucson, Arizona, studies on chromosome movement in translocations and in primary and tertiary trisomics has lead to the formation of "balanced" tertiary trisomic plants which produce pollen grains homozygous for specific recessive genes. Such pollen sources are of special interest for genetic studies, back mutation work, etc.

In a series of studies involving translocation break points, evidence is emerging that many of these points are localized and tend to fall near the centromere.

A defective seed character giving a small kernel was found to be mongenic and showed the xenia effect. The characters will be useful in genetic studies as a marker gene.

The following linkages or chromosome locations for genes were reported: Unicula and orange lemma are linked on chromosome 6 with a crossover of .4 percent; a gene for wide leaf is on chromosome 7; orange lemma and earliness are very closely linked on 6; and the genes conditioning leaf rust resistance and mildew resistance in the variety Franger are linked with a crossover of 16 percent.

4. Backcrosses. At Bozeman, Montana, additional backcrosses were made in an extensive improvement program with 2-rowed barleys. The objectives include improvements for the following characters: Stripe mosaic resistance, straw strength, root strength, hull-less seed, short plant height, shattering resistance, large seed, increased diastatic power, and small lodicules for loose smut resistance. In addition, 16 bulk hybrids in the F_4 or F_5 were advanced one more generation for eventual selection in F_6 or F_7 .

At Beltsville, Maryland, an extensive backcross program is underway with winter barley. Economically desirable genes as well as genetic marker genes are being transferred into agronomically adapted genotypes for use as parental breeding stocks and for genetic studies.

5. Special Crosses. At Brookings, South Dakota, a laboratory and embryo culture room was completed for use in a breeding program to transfer genes from related species and genera to cultivated barley, and to conduct the related cytological studies. Many of the characters desired (e.g. winterhardiness) do not exist within the cultivated species and we have to look elsewhere.

6. World Collection. The periodic increase and viability maintenance of the world collection of barley varieties was carried out at Aberdeen, Idaho this year. A total of 6,600 varieties was grown, and during the growing season each entry was carefully examined for stripe mosaic virus and those entries showing virus were discarded. Only a very small number of entries showed this virus.

7. Chemical Resistance. At Bozeman, and in cooperation with the Crops Protection Branch, 22 barley varieties were evaluated for their response to 7 herbicides. The yield of the variety was taken as an index of its response to the chemical. The greatest range in yield occurred with barban, where Munsing yielded 136 percent of its check and Freja only 12 percent of its check. The results substantiate the idea of improving weed control by either using resistant varieties or breeding them for this trait.

At Madison, Wisconsin, applications of thimet at seeding time again increased the yield of barley. The yield of Kindred was increased 7.3 percent and 3.1 percent for Barbless, the greatest increase being obtained at the lighter seeding rate. Varieties showing resistance to Karmex spray were Vaughn, Hanna, C.I. 4935, and Bachue.

8. New Varieties (Winter). Four new winter barley varieties were released to certified and/or foundation seed growers. The variety Wade was developed and released in North Carolina. It is a short-awned variety with high test weight, strong straw and moderate resistance to scald, leaf rust and mildew. James was developed and released by the Virginia Agricultural Experiment Station. It is an awnleted type, moderately resistant to leaf rust, mildew and lodging and is earlier and higher yielding than Wong. Dutchess was developed and released by the Cornell Agricultural Experiment Station. It is somewhat shorter and later than Hudson with a very strong straw and threshes more readily than Hudson. Chase was developed cooperatively by ARS and the Nebraska Agricultural Experiment Station and was released in Nebraska. It is very winterhardy, and much superior in lodging resistance to other hardy varieties grown in the northern area.

9. New Varieties (Spring). At Fargo, North Dakota, the North Dakota Station announced the naming and increase of 2 new barleys, Trophy and Larker. Both varieties are superior in kernel plumpness to the presently grown malting varieties, Traill and Kindred. They were selected from a cross, Traill x U.M. 570. Trophy and Larker both are 6-rowed and with a white colored aleurone. Trophy is rough-awned white, Larker is semi-smooth. In yield performance, Trophy and Larker have been superior to Kindred and compare favorably with Traill and the high-yielding, non-malting varieties. The disease reaction of these new varieties is similar to Traill and Kindred, but Trophy seems to have some field resistance to prevalent races of net blotch. Malting and brewing tests have been generally satisfactory, but final acceptance will depend on more extensive tests.

10. Pulvinus. At Madison, Wisconsin, observations on the pulvinus in barley indicated that this organ may contribute to straw strength. The pulvinus is the visible swollen part of the leaf sheath falsely referred to as the node. In stiff-strawed varieties the pulvinus is short and rounded, and covered with a waxy bloom that may retard water absorption. In weak-strawed varieties the pulvinus is much longer and when the stem ripens the pulvinus shrinks, becoming concave. This is a much weaker structure, absorbs moisture, becomes leathery, and bends easily. If further observations on this organ agree with those carried out so far, the shape and size of the pulvinus may become a criterion for selecting stiffness of straw.

11. Seeding Depth. In tests at Logan, Utah, a positive correlation was found between winterhardiness and the depth of crown setting in winter barley.

B. Diseases

1. Physiology. At Lincoln, Nebraska, studies were made comparing the protein structure of healthy, as well as diseased plants, to learn more about the physiological changes that occur when plants are infected with plant viruses. The serological procedures used in these studies included are immunoelectrophoresis and agar double diffusion, Ouchterlony technique. Techniques are now being improved to determine the significance of the differences observed between healthy and virus-infected plants.

2. Stripe Mosaic. At Fargo, North Dakota, the equilibrium level of barley stripe mosaic virus transmitted from year to year in susceptible and resistant varieties was determined. The susceptible varieties were found to have from 20 to 60 percent of the seeds infected with the virus depending upon the season. Some resistant varieties were found to have less than 5 percent of their seed infected with this virus. The virus was found to remain viable for at least 18 months following lyophilization and storage at -15° C. Only 69 varieties from the world collection of barley maintained by the U. S. Department of Agriculture of over 6,000 entries which were examined were found to have the barley stripe mosaic virus. Virus-free seed of these varieties is being increased before the varieties are placed in permanent storage.

3. Pathogenicity of Helminthosporium. Studies have been made of the pathogenicity of the Helminthosporium species at Raleigh, North Carolina. These studies indicate the various species of this fungus have a wide host range. Crosses between species have resulted in the production of progeny with greater pathogenic potentials than either parent species. The differences in genes for pathogenicity between species suggests a dynamic and continuing evolution within the genus Helminthosporium.

4. Host-Pathogen Genetics. At Beltsville, Maryland, the relationships of several genes conditioning the pathogenicity of the fungus which causes powdery mildew were determined. Some genes were inherited independently and others were closely linked or allelic. It was shown that the relationship of the genes in the pathogen may be important in determining the combinations of genes conditioning resistance in the host which should be used in breeding programs.

5. New Sources for Resistance. The variability of Hordeum species and pathogens on those species, is being studied in Israel, which is within the area where cultivated barley is thought to have originated. This research is being sponsored under Public Law 480 project A10-C-R-1. Over 100 collections of Hordeum spontaneum and other Hordeum species have been made. Several of these collections have been found to be resistant to the diseases: Net blotch, powdery mildew, leaf rust, and stem rust. Many strains of the fungus causing net blotch, powdery mildew, and the rust have been isolated in that country.

C. Varietal evaluation (quality)

1. Varieties from State and Federal Breeding Programs. As in previous years, a large number of barley varieties and promising selections from breeding programs were evaluated for quality. The laboratory located at Madison, Wisconsin, serves both Federal and State breeders across the nation in this quality work. The results are made available as quickly as obtained. In addition to variety evaluation, the laboratory also determines the effect of fertilizers, herbicides, and other cultural practices on malting quality. A brief description of the kind of material tested follows: (1) Varieties from 3 uniform nurseries which cover most of the barley areas from which malting barley is bought, and (2) individual sets of varieties from 11 states, ranging from 18 to 300 in number were evaluated this year. The most promising selections from this overall testing program were also evaluated for brewing quality.

2. Effect of Chemicals on Quality. With the increased use on barley of herbicides and other chemicals, quality tests were initiated several years ago to determine if any of these chemicals have an effect on quality. The general pattern that is emerging is that these chemicals either affect or do not affect quality, and in the case of those that do, it is the nitrogen component that is disturbed. Of the 5 herbicides investigated during the year, Barban, Silvex, and 2,4-D affected quality, whereas, 4(2,4-DB) and 2(2,4-DP) showed no effect.

Since the FDA approval of gibberellic acid for use on barley during malting, there has been increased interest in the possible use of other growth regulators. A total of 9 regulators including gibberellic acid were investigated during the year. The regulators giving the greatest effect were: Gibberellic acid, 2-chloroethyl-trimethyl ammonium chloride, 3-amino-1,2,4-triazole, and Kinetin; and of these, there was a general stimulation of growth from the first chemical, an inhibition from the second chemical, a general overall stimulation from the third chemical, and both desirable and undesirable changes from the fourth chemical. The effects of the remaining regulators were erratic, spotty, or indifferent. The results are of great interest and suggest that industrial applications need to be considered.

The specific effect of some of the chemicals also suggests there may be a genetic basis for this specificity.

3. Effect of Microflora. Since all barley kernels are infested with a diverse flora of microorganisms at harvest or during storage, a select sample of the most commonly occurring microorganisms was investigated for their effects on quality. The results, using 30 isolates of Fusarium, show that significant changes were measured for the following factors: (a) Increased steep and respiration loss, (b) decreased rootlet growth, (c) decreased malt recovery, (d) increased extracts (e) increased alpha-amylase, (f) increased wort nitrogen, (g) increased formol nitrogen in wort and beer, (h) increased free amino acids in brewery wort (i) decreased brewery wort dextrins, and (j) decreased clarity and gas stability of beer. From these results it is evident that this group of microorganisms can markedly alter the properties of malt and beer. The causes for these effects have not been worked out, but the following possibilities are suggested: A gibberellic acid effect, since some of the isolates are known to produce this factor; the enzymatic changes may be due to a stimulation or inhibition of the enzyme normally produced in the barley; or the barley enzyme may be augmented by a parallel synthesis of the same enzyme by the fungus.

4. Germination Inhibitor. A potent inhibitor of barley germination produced by one of the isolates mentioned in the preceding paragraph has been further purified by chromatography. In its present form its toxicity is about 25 times that of mercuric chloride. Compounds having a toxicity of this magnitude warrant further investigation.

5. Amino Acids. A Mark II automatic amino acid analyzer, recently modified to include refinements and improvements is proving out very well. The limited data obtained support the genetic individuality of the free amino acid content of different barley varieties. This type of information should be of great diagnostic value in studying varieties and malting quality. Another example of the use of this apparatus is to determine the amino acid picture from malts treated with gibberellic acid. Here it was found that all amino acids were increased except tryptophan, which was notably depressed. Another improvement to the Mark II was the insertion of a flow cell in the effluent stream to allow ultraviolet spectrophotometer readings to be made. This procedure does not interfere with the amino acid determination and allows an evaluation of nucleic acid derivatives. The implications of this information to genetics may be of considerable importance. Work is planned in this direction.

6. Effect of Drying Temperature on Quality. Since artificial drying of barley at harvest is becoming an increased practice, studies were conducted to determine how high a temperature could safely be used. By following an exact dry schedule it was found that temperatures up

to 140° F. could be used without damaging the grain or affecting its quality.

7. Effect of Genetic Factors. Five isogenic pairs contrasting glossy stem and normal showed no difference in quality. In the isogenic pair differing for lemma color (white vs. normal), the white lemma mutant was higher in nitrogen and had smaller kernels. The quality differences were those expected for higher nitrogen and kernel size.

8. Brewing Tests. The new European varieties Firlbecks III and Piraline were superior to the standard Hannchen variety in brewing quality. Plans are underway to release these two new varieties. Brewing quality was not affected by the new wild oat herbicide Barban when applied in the field in the seedling stage.

D. Culture (Physiology)

1. Winterhardiness. At East Lansing, Michigan, research studies on the winterhardiness of winter barleys dealing with metabolic effect occurring at low temperature, showed the effects were most pronounced when the temperature was just above the freezing point of the soil solution. Changes occur very slowly in the sub-freezing range as a result of the partial dehydration of the tissue. At temperatures near 35° F. the rate of formation of new tissue more than compensates for the degeneration of tissue previously formed at higher temperatures. Plants become hardy during the first few weeks at a temperature near freezing, attaining an optimum physiological condition in 3 to 4 weeks. The killing temperature at this time is in the range from 0° to 28° F., depending on the hydration state. Loss of hardiness parallels degenerative changes which become obvious with longer periods at low temperature. Plants held near 35° F. do not regain hardiness as new tissue develops.

A study is being made to identify diffusible substances in guttation water, and to determine if any specific substance is related to the degenerative process and thus to hardiness.

2. Ice Crystal Patterns. In other studies, the relative hardiness of varieties in a hydrated condition seems to be greatly affected by the pattern of ice crystal formation in the crown. The crystal patterns are being studied by sectioning the crowns of frozen plants and placing the frozen sections in cold oil under a cover slip on a glass slide. Water droplets which form as the section thaws have been found to occupy the positions which previously contained the crystals. The water droplets can be seen and photographed more clearly than the crystals. The study showed that small crystals are found in tissue resistant to freezing, whereas larger masses of ice occur in sensitive regions. Similar differences in crystal size were found between hardy and non-hardy varieties when homologous tissue sites were compared from the two varieties.

3. DDT Analogues. A study was made at Beltsville, Maryland, with a series of 23 analogues of DDT on their reaction to a resistant and a susceptible variety of barley. Four analogues reacted similarly to DDT, whereas, in 19, both varieties were resistant. The molecular structure of the analogues was studied and this indicated that the structure of the molecule was more important than its composition in determining the reaction to the two varieties.

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CORN AND SORGHUM CULTURE, BREEDING,
DISEASES, AND VARIETY EVALUATION
Crops Research Division, ARS

Problem. The combined production of corn and sorghum totals approximately 4 billion bushels annually and constitutes roughly eighty percent of our feed grain. The rapid expansion and near self-sufficiency of the hybrid seed industry requires an extensive reorientation of the current programs to give increased emphasis to basic research in genetics, physiology, and pathology. Some progress has already been made in giving greater emphasis to such needed research. Corn and sorghum production are dependent upon the utilization of hybrid vigor but no adequate genetic explanation of this phenomenon is currently available. In addition to basic research on this topic, additional information is needed on the relative efficiency of different breeding systems and the basis and mode of inheritance of disease and insect resistance. Increased efforts are needed in genetics and physiology to provide information basic to improvements in the nutritional and industrial qualities of the grain. Work is needed on mineral nutrition and the patterns of synthesis of protein, oil, and carbohydrates. More work is needed in pathology to determine the basis for resistance and the capabilities of disease organisms to become infectious on currently resistant types and to explore the whole host-parasite interaction system.

USDA PROGRAM

The Department has a continuing long-term program involving geneticists, physiologists, pathologists, and agronomists engaged in basic and applied studies relating to the improvement of corn

and sorghum. Corn research is conducted at Beltsville, Maryland; Charleston, South Carolina, and in cooperation with State Experiment Stations at the following locations: Tifton, Georgia; Urbana, Illinois; Lafayette, Indiana; Ames, Iowa; State College, Mississippi; Columbia, Missouri; Raleigh, North Carolina; Wooster, Ohio; Brookings, South Dakota; Knoxville, Tennessee and Madison, Wisconsin. Research on sweet corn is conducted at Charleston, South Carolina. Sorghum research is cooperative with State Experiment Stations at Manhattan and Hays, Kansas; Lincoln, Nebraska; Stillwater, Oklahoma; Brookings, South Dakota and Chillicothe and College Station, Texas.

Four PL-480 projects dealing with corn are now in operation. These are A-18-CR-2 "Fungicidal control of downy mildew of corn and the resistance of corn varieties, hybrids, and inbred lines to downy mildew"; E-25-CR-1, "Factors affecting the frequency of monoploid seedlings in maize and their subsequent diploidization"; S-3-CR-37, "Evaluation of corn and beans native to Central and South America as sources of germ plasm for use in breeding programs in the U.S."; and A-7-CR-19, "Carbohydrate Metabolism in the Tapioca plant (Manihot utilissima)".

The Federal research effort devoted to corn and sorghum totals 32.0 professional man-years. Of this number 24.0 is devoted to breeding and genetics, 5.0 to diseases and 3.0 to culture.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Stations in 1961 reported a total of 64.6 professional man-years devoted to breeding and genetics, 10.7 to diseases, 16.2 to varietal evaluation and 15.7 to culture.

The hybrid seed industry and processing companies have extensive programs for the development of inbred lines and the evaluation of such lines in hybrid combinations. Research on disease and insect resistance and various aspects of genetics is done as needed. The results of this research are reflected in the quality of the material developed. The lines developed, however, are not released for general use and in many cases the research findings are not published. It is estimated that the corn and sorghum seed industry devotes the equivalent of 77 man-years to breeding and genetics, diseases, varietal evaluation and culture studies. The processors and private seedsmen concerned with the development and evaluation of sweet corn are estimated to have annual expenditures equivalent to 50 professional man-years.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Breeding and Genetics

1. Corn. Genetic studies at the Missouri Agricultural Experiment Station at Columbia have been concerned with the sequence of gene action in anthocyanin synthesis and with conversion, a mutation-like phenomenon. The use of paired segments of aleurone tissue of different mutant types has established the sequence of gene action to be:

$$C^I - C_1 - C_2 - R - In - A_1 - A_2 - Bz_1 - Bz_2$$

Pigment synthesis is visualized to proceed in sequential gene-controlled steps, each step being required if the end product, pigment, is to be obtained.

Studies on conversion have involved the B locus, one of a series of genes affecting anthocyanin development in the plant. A new type designated B^I , has been shown to be able to convert B so that no B types are obtained in the progeny of B^I/B crosses. A mutable allele B^V can also be converted to B^{VI} . However, mutability and conversion at this locus appear to be unrelated processes.

Cytogenetic studies underway at the Missouri Agricultural Experiment Station involve several aspects of the effect of chromosome structural dissimilarity on pairing affinity. A high degree of preferential pairing was observed in trisomic plants carrying 2 normal and 1 exotic chromosome 3. This indicates structural dissimilarity and would tend to limit the incorporation of desired genes from exotic sources. The possibility of developing a true breeding artificial allotetraploid corn is being investigated. Such a type would require creating a corn genome whose chromosomes were so structurally dissimilar to standard that competitive pairing would be eliminated. Such a hypothetical strain would be true breeding and retain the superiority of the F_1 hybrid.

The use of certain translocations or overlapping inversions should permit the isolation of chromosomes carrying certain desired genes in duplicate. The genes under study are Y₁, wx, su₁ and ae. Each of these genes is of interest because of special nutritional or industrial properties. The effects of such duplicated segments remain to be determined.

In studies conducted at the North Carolina Experiment Station estimates of additive and dominance variances in different kinds of populations have suggested the following conclusions: 1) additive

genetic variance in populations derived from single-cross hybrids is of the same general magnitude as that found in open-pollinated varieties, 2) F_2 populations of single-crosses yield larger estimates of dominance variance than varieties but advanced generations of the same crosses indicate this is dissipated by recombination of loose linkages and that the estimates in F_2 are biased by linkage, 3) F_1 variety crosses appear to have less additive variance than the parental varieties, and 4) the advanced generation of the variety cross appears to have more additive variance and relatively smaller or no dominance variance.

Comparisons involving homozygotes (AA) versus heterozygotes (Aa) have been made at Beltsville, Maryland and at the Mississippi Agricultural Experiment Station. For the most part these comparisons have involved naturally occurring or induced mutations in an inbred background. In no case has the superiority of the heterozygote been demonstrated. In several cases the heterozygote has been significantly inferior to the homozygote. These studies have a bearing on gene action involved in heterosis.

The cytoplasmic male sterility of JC33-16 (J type) has been transferred to the lines Ky27 and K55 without modification of the sterility. In crosses to fertility restoring strains (Rf) an excess of fertile plants is obtained in F_2 . The data suggest either (1) a differential elimination of non-fertility restoring, (rf), gametes or (2) a slower rate of pollen tube growth for rf gametes.

Studies were continued at the Iowa Agricultural Experiment Station on maturity and its inheritance in crosses between inbred parents chosen for differences in time of silking and moisture content at harvest. Physiologic maturity was attained approximately 60 days after flowering. Dominance and epistatic effects were shown to be of importance.

Studies on dwarf lines were continued at the Coastal Plains Experiment Station at Tifton. Plant height appears to be influenced by a modifier complex in addition to the major dwarfing gene. If the modification can be stabilized, the "tall dwarfs" appear to be best suited for commercial production.

High amylose hybrids have been developed which produced yields in excess of 100 bushels per acre in 1961. These hybrids were lower than average in test weight but compared favorably with dent hybrids in lodging, dropped ears, ear height and shelling percentage.

Work on the development of high oil types having satisfactory yield and other agronomic traits was continued at the Iowa Agricultural Experiment Station.

Commercial sources of Xanthophyll are desired by the broiler industry. Strains of corn having up to 60 ppm are available and are satisfactory in inducing the desired pigmentation in broilers. Selection and back-cross techniques are being utilized to produce high Xanthophyll lines and hybrids which will be acceptable to the farmer and to the poultry broiler industry.

Seven full-season white, six full-season yellow, three early white and eight early yellow inbreds were released through the Tennessee Agricultural Experiment Station at Knoxville in 1961. The early lines are prolific and are adapted to the plateau area. They have also shown promise in the Delta area as planting and harvesting need not compete with cotton. The full-season lines are generally adapted throughout the State and adjoining areas.

Two new inbred lines, Mo.12 and Mo.13, were released by the Missouri Experiment Station in 1962.

Crushing strength of stalk and rind thickness have been shown to be associated with resistance to stalk lodging. Some exotic strains have been found to have crushing strength values far superior to local commercial types. However, these exotic types have other undesirable characteristics such as tall plants and high ears. Studies are under way to try and combine high crushing strength and low ear placement.

The effect of hybrid reaction, nitrogen fertilization, and population densities on European corn borer infestation and damage was investigated at the Iowa Agricultural Experiment Station, Ames, Iowa. First brood corn borer infestation caused yield reductions in all except resistant hybrids. Yield losses from borer infestation increased with an increase in plant population. First and second brood damage are of essentially equal magnitude. Yield reduction due to second brood borers increases with increasing lateness of the hybrids.

Selection for resistance to ear worm has been continued in 2 synthetics for a 5-year period at the Missouri Experiment Station. Progress has been made in both synthetics; the better of which now compares favorably with the ear worm resistant hybrid Dixie 18.

Studies at the Tennessee Agricultural Experiment Station on artificial infestation of corn ears by corn ear worm larvae indicated; (1) six larvae per ear were sufficient, (2) eggs laid in the laboratory and transferred to developing ears produced greater damage than field oviposited eggs, (3) placing paired male and female pupae in cages over ears and allowing the moths to emerge, mate and lay eggs on silks was ineffective, and (4) there was no consistent relation between extent of damage and husk length.

2. Sorghum. Thirteen sorghum hybrids will be released by the experiment stations for seed production in 1962. The hybrids released from Nebraska and Texas have been developed cooperatively with ARS. All hybrids have been included in Regional Yield Trials. The hybrids are:

<u>Hybrid No.</u>	<u>Pedigree</u>	<u>Expt. No.</u>
RS617	Combine Kafir-60 x Mp10	Miss. Expt. 1
AK 614	Redlan x dwarf shallu	Ark. 56001
Ga 609	Combine Kafir-60 x S.A. 6399-3 sel.	
SD 502	Martin #1 x SD 100	SD 59106
SD 503	Combine Kafir-60 x SD 100	SD 59107
NB 504	Combine Kafir-60 x Day-Atlas 3494	Nebr. 76
NB 505	Martin x Day-Atlas 3494	Nebr. 77
RS 616	A606 x SA 3086	CE 0089
RS 615	A398 x SA 3086	CE 0087
RS 622	A606 x SA 3101	CE 0517
RS 621	A398 x SA 3101	CE 0515
RS 623	A399 x SA 3101	CE 0519
RS 624	A378 x SA 3101	CE 0520

The first three hybrids will be grown in the Southeastern states. Their brown seed has bird-repellent qualities in the immature stages, and resistance to seed mold and sprouting when mature. SD 502, SD 503, NB 504, and NB 505 are early maturing and similar to RS 501 except shorter in plant height. The remainder of the hybrids listed are known as 3 x 4-dwarf types. The 3 and 4 refer to the number of recessive genetic height factors in the parents. All other experiment station releases have been 3 x 3-dwarf types. These new hybrids combine resistance to head smut with short stature.

Two sorgho hybrids will be released for seed production in Nebraska in 1962. These are:

<u>Hybrid No.</u>	<u>Pedigree</u>	<u>Exp. No.</u>
NB 304F	Highland-Atlas 4692 x Rox	Nebr. 74
NB 305F	Highland-Atlas 4692 x White Collier	Nebr. 75

These will be the first forage hybrids which will have sorgho types (sweet and juicy) for both parents.

Broomcorn breeding is being conducted in Oklahoma. A problem in breeding broomcorn is getting a new variety accepted by the industry.

A new dwarf broomcorn (Ex. x O Stem-1-2) has been developed which produces high yields of a good brush. Distribution of seed will depend upon the reaction of the growers and processors.

F₂ plots of RS 610, RS 630, and Texas 660 yielded 10% less grain than the F₁ hybrids in tests in Texas. In Nebraska the F₂ hybrids of RS 501, RS 590, RS 610, and RS 650 yielded 12% less than the F₁ hybrids as an average of 3 tests. These yield differences in Nebraska were almost entirely due to a reduction in number of seeds per head. Several studies have demonstrated that the yield advantage of an F₁ hybrid over its parents is due largely to an increase in number of seeds per head. The emphasis in breeding has shifted from 3-way hybrids to shorter types possible from use of 4-dwarf lines. Within the next few years a majority of the hybrids will be produced by using 4-dwarf seed parents and non-mutating 3-dwarf pollinators. Eventually all 3-dwarf lines will be of the non-mutating type. The use of these lines will eliminate a major problem in seed production; the necessity of roguing tall mutants from the male or pollinator rows. The number of tall plants now found in hybrid fields will be greatly reduced.

A second cytoplasmic male-sterile system has been discovered. The F₁ plants from crosses using the variety 9E from Ghana as the female are male-sterile. The sterility is the result of the failure of the anthers to dehisce. The pollen held by the anthers appears to be normal.

Several varieties have been crossed to the original F₁ plants and the resulting hybrids are male-sterile. Male-sterile lines have been developed by continued backcrossing. These lines are good steriles in Nebraska as determined by their failure to set seed under selfing bags. The probability of the anthers on these plants remaining non-dehiscent under a range of environmental conditions has not been determined. No variety has been found which will produce a fertile F₁ plant when crossed to these steriles. When the 9E variety is used as the male in crosses, the F₁ plants are fertile.

A study was made to determine the effect of radio-frequency electric fields on seed germination and mutation rate. This work was done in cooperation with the Farm Electrification Research Branch. The results were negative. There was a progressive deleterious effect on germination with the increased period of exposure, and the mutation rate as determined by the frequency of seeding mutants in the second generation was no greater than in the controls. A high speed centrifuge was used in Kansas to check its effectiveness as a mutagenic agent. The germination of the seed was reduced with the most severe treatments but no mutant variants were detected in the first generation. Diethyl sulfate was tried as a mutagenic agent in Texas. Its effectiveness will be determined in subsequent generations.

Cytogenetic studies are being conducted in Nebraska and Texas. Several trisomic plants and translocation stocks have been developed and will be used to locate genetic factors into linkage groups. Ovule and pollen abortion have been determined from F_1 plants from three translocations intra-crossed and crossed with normal plants. The average ovule and pollen abortion from the three F_1 crosses with normal was about 62%. The range which has been found suggests that chromosome disjunction is genetically controlled.

A metaxenia experiment was conducted in Kansas in 1960 and 1961, and in Nebraska in 1961 for the purpose of studying the effect of the pollen parent on seed weight and volume. The rate of translocation from the stalk into the seed was also measured in the 32 crosses.

B. Diseases

1. Corn. Studies on the genetics and pathogenicity of Helminthosporium species conducted at the North Carolina Experiment Station indicate (1) most Helminthosporium species are pathogenic to a wide variety of gramineous hosts, (2) intra-specific variation is common among the species tested (3) hybrid progenies from certain interspecific crosses were pathogenic to host species that were highly resistant to both parental strains, and (4) that toxin production in crosses involving H. victoriae is genetically controlled and quantitatively inherited.

An inheritance study of resistance to Diplodia stalk rot by means of a diallel analysis of F_1 's and parents indicated a significant interaction between parents and their respective F_1 hybrids. Additive genetic variance was high.

A comparison of 4 methods of stalk inoculations with Diplodia maydis, Macrophomina phaseoli and Gibberella zeae was made at the Purdue Agricultural Experiment Station. Differences were observed among hosts but little difference was found among inoculation methods.

Inheritance studies involving resistance to southern corn rust, Puccinia polysora, are being conducted at Beltsville, Maryland and Lafayette, Indiana. Several distinct biotypes of the pathogen have been identified. Sources of resistance are available for each of these types. Instances of dominance and recessivity of resistance have been observed. Some of the observed F_2 segregations indicate a monogenic basis while others suggest a more complicated type of inheritance.

Two new molds affecting corn in storage have been isolated at the Wisconsin Agricultural Experiment Station. One of these, Gonotricium sp. was isolated in high frequency, while the second Piricauda sp. was observed less frequently.

Inoculating plants 18 inches high with a water suspension of chlamydo-spores through the side of the plant above the growing point has been the most effective method of producing corn smut artificially. Other methods are equally effective on susceptible material but less effective on resistant lines or hybrids.

2. Sorghum. The nature of charcoal rot and the conditions under which it develops were investigated during 1961 in Kansas. The severity and high rate of mortality normally observed in the field when charcoal rot is severe were duplicated in electrically-heated soil beds in the greenhouse, using steam-sterilized soil and pure-culture inoculum of Macrophomina phaseoli. A moisture stress period of only four days immediately prior to inoculation was sufficient to predispose the plants to charcoal rot. This was accomplished by providing a daytime air temperature peak of 115° F. and soil temperatures of 95° F. and 105° F., causing a rapid rate of plant transpiration and evaporation of moisture from the soil surface. Available soil moisture was recorded tensiometrically to be 25% or less for plants receiving stress. No rot was visible in the stalks of plants not subjected to moisture stress. Plants that had undergone anthesis 2 weeks or more before being subjected to moisture stress were usually killed 3-5 days and 5-6 days after inoculation at the 95° F. and 105° F. soil temperatures, respectively. There were no intermediates--plants developing the disease were killed. The number of nodes showing severe rot was less in plants at 105° F. than at 95° F. since the parasitic activity of the pathogen ceases by the time the infected plant is killed. The severity of rot was most acute just above the nodal plates, especially in nodes not completely rotted. The anthocyanin produced by the plant in response to infection becomes depleted very rapidly as the dormant, sclerotial stage of the pathogen forms during the terminal phase of the disease. The use of field plots for testing plant materials with Macrophomina phaseoli may be practical only in arid climates. An attempt is presently being made to identify the substrate which forms or becomes concentrated in the lower nodes of plants subjected to a moisture stress as physiological maturity is approached.

No effective method for the stimulation of Sphacelotheca reiliana (head smut) chlamydospores to germinate has been found. Certain culture media, such as yeast extract and malt extract agar, have been slightly better than others, but the percentage of chlamydospore germination is less than 1% for most collections. Three collections out of a total of 56 have exhibited 43-68% germination. Single sporidial cultures have been isolated from these and at the present time are being mated to identify compatible types.

Culture and Physiology

Corn. Evidence is clear that DNA is the carrier of genetic information. This information is relayed in some manner by RNA which is also involved in protein synthesis. Ribonucleases are enzymes which have the ability to degrade RNA but they also have some capability to reform nucleotide chains. Evidence for 3 ribonucleases has been obtained from studies of germinating corn seedlings. The specific function and characterization of these enzymes is being actively investigated at the Illinois Agricultural Experiment Station at Urbana.

The differential yielding ability of hybrids under heavy fertilization and high plant populations has been demonstrated at the Mississippi Agricultural Experiment Station. Dixie 55 and Dixie 22 produce comparable yields under normal planting conditions. With heavy fertilization and a population of 19,600 plants per acre relative yields of these 2 hybrids were 178.6 and 135.1 bushels respectively. Under these conditions of high yield both stalk lodging and ear height were excessive. The need for hybrids specifically bred for response to high soil fertility becomes increasingly evident.

Six double-cross dwarfs were compared at 4 population densities (8700 to 21,750) plants per acre. All hybrids exhibited increased yields when stands were increased from 8,700 to 13,050 plants per acre. Additional gains with 17,400 plants were smaller and nearly the same for all hybrids. No significant increases in yield were observed at 21,750 plants per acre. This group of hybrids, therefore, will not tolerate as high plant populations as the normal height hybrids commonly grown.

Three single-cross hybrids were used to study the effect of partial defoliation on prolificacy and yield. At a specific stand level it was found that 1/2 the leaves could be removed at anthesis without a significant effect on yield or number of ears per plant. These results suggest that potential yield is limited more by efficiency of translocation than by photosynthesis.

A comparison of high amylose hybrids at 4 stand densities revealed that the highest amylose percentages and test weights were obtained at the lowest plant populations. High amylose was also associated with high nitrogen level, although the differences were small.

2. Sorghum. Tests on chemical control of weeds in sorghum were conducted in Kansas in cooperation with the Crops Protection Research Branch. Ten hybrids were given three treatments; propazine pre-emergence, atrazine post-emergence, and cultivation. Stands were not reduced by the propazine treatment. The treated plots average 5% higher yields than the cultivated. Propazine applied at the same rate (3 lbs. per acre) on a lighter, more sandy soil seriously reduced stands.

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WHEAT AND RYE CULTURE,
BREEDING, DISEASES AND VARIETY EVALUATION
Crops Research Division, ARS

Problem. Wheat is grown commercially in 39 States and to some extent in the other 11. Likewise, rye is widely cultivated. Together they have represented a harvest of at least 58 million acres annually--over 15% of the cropland used for crops in the U. S. Both crops are subject to a wide range of environmental influences which affect varietal responses. Diverse pests, especially certain fungi and viruses, and some insects, adversely affect susceptible varieties. Quality is affected by genetic and environmental factors. For these and other reasons, a widely deployed research program is essential to cope with the diverse maladies and problems, many of which are, by their very nature, continuing problems.

USDA PROGRAM

The Department has a long-range program of research and research leadership in wheat and rye investigations. The objectives of the research are to stabilize production by reducing losses, to increase efficiency of production, to improve the quality of wheat and rye wherever grown in the United States, and to accumulate and disseminate knowledge. This basic and applied research program is performed in the laboratory, greenhouse or field and involves the sciences of agronomy, ecology, physiology, genetics, cytology, pathology, entomology, chemistry, physics, and statistics. Regional and national leadership is given to several phases of the work.

The primary Federal effort is concentrated in 10 research centers. Twelve additional locations are required either to provide proximity to the location of the problem, or to take advantage of facilities or contacts with workers located at such stations.

Basic and applied work on three rusts of wheat, four smuts, two Septoria diseases, four viruses, several root rotting organisms, mildew, and numerous other diseases to obtain means of control receive the attention of 19 professional employees. In four centers, quality testing and evaluation of varieties and basic chemistry and technology research utilize 20 professional employees. The numerous aspects of quality come into prominence in all breeding programs (state, federal, or private), and chemical treatments, soil management and farm handling practices all have an influence on levels of quality that may result in what the farmer sells. Basic work on wheat genetics and the development of improved germplasm and breeding of new varieties involves 18 professional workers. Included is basic work to transfer useful genes to wheat from other species of plants, learn the inheritance of important characters, study, catalog and maintain the World Collection (about 17,000 accessions), and breed

new types of wheat for special purposes (e.g., semidwarfs, higher protein flour, more combinations of genes for insect and disease resistance). Leadership in each of the four major wheat regions facilitates state-federal regional planning of certain tests, obtains uniform quality tests, and promotes exchange among workers of seed stocks, data and useful information. Culture, physiology, hardiness, stand establishment and other such problems utilize 3.4 professional men. The cost of this research is estimated at about 2¢ per harvested acre of the crops concerned.

Under the Public Law 480 program six wheat and rye research projects are sponsored in Poland, Egypt, Spain, and Israel. These include work on rusts, smuts, and root systems of wheat, natural hybridization in relation to the origin of wheat and rye, and the use of polyploidy in rye breeding.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Stations in 1961 reported a total of 58.5 professional man-years on wheat divided among subheadings as follows: Breeding and Genetics 29.9, Diseases 12.5, Variety Evaluation 9.3, Culture 6.8. Much of this work (over 1/2) involves the breeding and testing of new varieties for local suitability. Greatest emphasis appears in work conducted in the north central region (23.8 man-years).

Industry is active in at least three research areas; namely, chemicals for disease control (9 man-years), milling and baking research (8 man-years), and seed company research (3 man-years).

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Breeding and Genetics

1. New Varieties. New varieties officially released jointly by ARS and State Experiment Stations are given below:

Big Club 60 - A white grained, club wheat for California replaces Big Club 43 and is superior in yellow dwarf resistance and stem rust resistance.

Gaines - A white grained, winter, semidwarf for use in Washington, Oregon, and Idaho. This is the first semidwarf to be released in the United States. It is highly resistant to common bunt, (except Race T-18) and moderately resistant to stripe rust.

A short stem wheat accession from Japan (P.I. 156691) was used in the cooperative breeding program of the University of Washington and Oregon Agricultural Experiment Stations and the U. S. Department of Agriculture in the development of the short stem 'Gaines' variety, one of four new wheat varieties released in 1961.

Justin - A red grained, spring bread wheat for use in North Dakota and nearby states. It is a high quality variety with a broader base for stem rust resistance than Selkirk.

Lemhi 62 - An improved Lemhi-type variety that was bred at the Aberdeen, Idaho station in cooperation with ARS. It incorporates stem rust resistance to important western races. A bunt resistant Lemhi-type is also under development at this station. The Lemhi-type is most useful on the irrigated lands of the Inland Empire.

Two new selections of soft red winter were increased in Indiana. One promises to replace Dual which it excels in yield, straw strength, and leaf rust resistance, and the other an improved Knox having resistance to hessian fly. Idaed 59 was developed and released by the Idaho Agricultural Experiment Station using certain basic stocks from USDA for parents. This white spring wheat is adapted in Idaho and adjacent states. It is resistant to stripe rust and some races of stem and leaf rust.

2. Cytoplasmic Male Sterile. Stocks were observed in T. timopheevi hybrids, giving a new source to supplement that already available from Aegilops. This is the first step in the possible development of hybrid wheat. Good pollen restorers were not found.

3. Perennial Wheat. Two releases of Triticum x Agropyron bulk stocks were made (California). These are C.A.S. 10180 (C.I. 13724) and C.A.S. 10185 (C.I. 13671). Seed was made available to seed companies with breeding programs and was not released for direct commercial production. The diversity of these stocks is very great, including some tendency to perenniality.

4. Agropyron Derivatives. Leaf rust immune early maturing selections derived from A. elongatum crosses gave agronomic performance on a par with standard varieties in Oklahoma tests. C.I. 13523 represents a natural translocation race in which an Agropyron segment bearing a gene for resistance to leaf rust has been inserted in a wheat chromosome. A single dominant gene appeared to control leaf rust resistance in the seedling plants. X-rayed plants from the F_1 of Wichita² x TAP48 yielded cytologically unstable lines of the general type desired. One plant had 42 chromosomes.

Streak virus immune plants with 2 extra chromosomes ($2n = 46$) were crossed with Wichita. Early observations indicate the immunity is diluted when either chromosome is lost. Stocks to prove this and provide immune 42-chromosome breeding stocks are being developed.

Over a thousand Sando lines were classified for mildew and leaf rust resistance with 93 and 192 being highly resistant or immune, respectively.

5. Mutations. An awned Thatcher from radiation treatment (AEC) was almost identical to the parent form except for much longer mixing time. This is being retested and may mark a decided step toward improved mixing quality. Various chemical mutagens are being used to induce variability of genetic interest. Chromosome 6B(X) carries the Aegilops umbellulata gene for leaf rust resistance as a single block of chromatin. The long arm of this chromosome carries a gene for stem rust resistance and the closely linked pollen killer locus.

6. Danne Wheat Collection. The Danne wheat collection consisted of 822 viable stocks of which 563 appeared to be different after duplicates were eliminated. Various types of trials were conducted on these depending upon amount of seed and the records Mr. Danne left to the USDA and Oklahoma State University.

7. Greenbug Resistance. Greenbug resistant selections (ENT) are beginning to appear in the advanced yield trials and some appear to have good agronomic characteristics. In one Oklahoma test infested with bugs, 4 selections yielded 12.1 to 17.7 bushels per acre compared to the Ponca check at 1.4 bushels per acre. Greenbug resistance from Dickinson Selection has now been transferred through three backcrosses to Concho and Tascosa in Texas. Parents and hybrid populations for studies of seed size and test weight, and of maturity were grown and are being analyzed.

8. Genetics of Durum Wheat. Tests of F_3 and backcross- F_2 generations in North Dakota corroborated the hypothesis presented in 1960 that the resistance of Acme durum to stem rust race 11 is conditioned by at least 3 independent dominant genes. A cumulative action was indicated by 2 of the genes, each epistatic to the third and weakest gene. Two dominant, or partially dominant resistant genes were used to explain the resistance of Kubanka durum studied in a backcross- F_1 generation.

A test of the F_1 generation from the backcross, P.I. 192334 (Vernal x P.I. 192334), indicated that the resistance of Vernal emmer is conditioned by 3 dominant or partially dominant genes. Two of the genes conditioned identical reactions which closely resembled the reaction of P.I. 192334.

A test of an F_2 generation of 652 plants from the cross, Khapli x P.I. 192334, strongly indicated that Khapli emmer carries at least 3 dominant or partially dominant resistance genes. Epistatic gene action in the F_2 test was indicated by the 48:12:3:1 ratio obtained.

9. Semidwarf Durums. Semidwarf durums--medium in yield but having good rust resistance were observed in North Dakota. Added genes for vigor are needed in these wheats.

10. Further Inbreeding of Rye. Over 10,000 self and sib pollinations were made at Tifton, Georgia, resulting in 25% successful seed set. Twenty-four one-variety isolation plots were grown from which pure seed was obtained for use in further experimentation or increase. Gator selections with leaf rust and mildew resistance were emphasized. Rust resistant Explorer plants (48 selections) were allowed to interpollinate and the 3 bushels of seed obtained were sown for further increase. This crop was named Emory. Rust resistant Wren's Abruzzi plants (40 selections) yielded enough seed to sow about one acre of increase of open pollinated seed. The name Weser was attached to this seed.

Neither Emory nor Weser are released varieties. Hybrid vigor in F_1 's resulted in forage yields surpassing parental varieties in most cases. Several unusual genetic types appeared in inbred stocks of Gator including dwarf, slick leaf, and "timothy" head.

B. Diseases

1. Stripe Rust Tests Added. The International Rust Nursery, Puerto Rico special rust tests, and state-federal cooperative rust tests revealed many highly resistant wheats. Special observations made on stripe rust resistance showed several types of reaction are available in U. S. wheats but that, in general, certain South American and European varieties have a broader spectrum of resistance. No one wheat was resistant everywhere to stem rust.

In Oregon, losses from stripe rust up to 40% in yield were reported. Susceptible varieties were 35 to 41% below the long-time average yield, while resistant varieties were 13 to 15% below the long-time average.

2. New Gaines Variety. This new variety combines moderate resistance to stripe rust, bunt, and some races of leaf rust. It is adapted to the Pacific Northwest where stripe rust and bunt have caused heavy losses.

3. Chemotherapy. Nickel sulfate and maneb had additive effects in Minnesota rust fungicide tests. A nonphytotoxic oil carrier, EAPZ, was found. Use of this oil resulted in some of the best nickel-maneb control sprays tested. The epidemic was delayed 10 days by 2 sprays. The first spray was applied at heading, the second 6-12 days later depending on rain.

In Texas, complete control of damage from stem rust was accomplished by multiple applications of maneb. Results were: Check 10.4 bus. per acre, multiple maneb 30.8, and Ni-Mn., 2 doses 19.1.

Phytoactin gave excellent protective action, only slight systemic, and poor eradivative action in control of rust.

Nickel, cobalt, kinetin, and benzimidazole all prevented senescence of detached leaf tissue in a manner similar to mildew and rust pustules. Nickel, kinetin, and cobalt induced starch and nitrogen compound deposition at the site. Senescence phenomena associated with rust and mildew infection appears not to be related to the specificity of these organisms.

4. Liquid Nitrogen. Liquid nitrogen storage of rust spores preserved viability for 1 year with no indication of deterioration.

5. Bunt Control. P.I. 178383 was resistant to all common and dwarf bunt races in the Pacific Northwest and showed rapid seedling emergence. It gave zero dwarf bunt readings where some other varieties were 75% infected. This variety is also highly resistant to stripe rust. Bunt resistance in P.I. 178383 x Golden to races T1 and T15 showed 3 independent factors were involved. The same cross showed 4 genes for stripe rust reaction.

Hybrids between races of bunt appear to be relatively infrequent in nature and some that do occur give avirulent hybrids or have less virulence than the parent forms. All races are being systematically crossed to determine the extent of this hypothesis.

TCNA continued to give good control of bunt and flag smut. No race of bunt has emerged resistant to the toxic effect of HCB.

Wood shavings 1 inch deep placed around plants in mid-December doubled dwarf bunt infection.

Chelated heavy metals as fungicides resulted in mercury rating best, copper fair, and iron poorest, while cadmium and nickel were not effective. Versene and versonal chelates of copper gave beneficial results in combination with mercury in particular.

HCB is not taken into the plant and does not become systemic; its action appears to be one of exclusion.

Aerial application of HCB to an area of 3.64 acres at 12 lbs. per acre reduced dwarf bunt from 7.3% to 0.4%. This is the first aerial control of bunt.

Eight races of dwarf bunt are now recognized. D-3 has the widest host variety range but high resistance is expressed in P.I. 178383, P.I. 167556, and P.I. 17348. At present all commercial varieties in the U. S. are susceptible to one or more of these races. Avon, resistant in New York, was susceptible to races 1, 2, 3, and 4.

6. Snow Mold and Septoria. Five thousand and two hundred World Collection items were tested for snow mold reaction in Washington. Best results were obtained with Agropyron hybrids, and with wheat from Poland, Russia, China, Iran, Afghanistan, and Turkey. These will be rechecked and others tested. A similar set of tests is being conducted at Aberdeen, Idaho.

S. nodorum resistance (or escape) was observed in certain species of Aegilops (Ae. triaristata) and in some varieties in tests at Beltsville, Md., and Raleigh, N. C. From the first 3000 World Collection items, 10% were worthy of a retest. Seedling and adult plant reactions do not always correspond and many promising varieties prove to be susceptible in retests.

7. Mildew. Plants susceptible to mildew as seedlings may become progressively resistant as they advance in stage of development. This depends upon race of mildew, variety, and stage of individual tiller. The change-over generally occurs between jointing and boot stage.

Monogenic mildew resistant lines were advanced by backcrossing.

8. Stem Rust Epidemic Stopped. Kaw, and Ottawa, especially, and Omaha, were resistant to the stem rust in Kansas that took a 7% toll of the State's wheat production. All of the leading varieties of spring wheat were resistant and no loss was suffered in the spring wheat belt in 1961.

9. Virus Assay. A density-gradient flow densitometer was developed in Nebraska to record the ultraviolet absorbance at all depths in a centrifuge column, and for collection of consecutive samples. The system gives reproducibility equal to an ultracentrifuge. A leaf-tip dip technique was used for wheat (soilborne) virus assay by electron microscopy.

C. Variety Evaluation (Quality)

1. New Varieties Approved for Quality. Gaines, Justin, Big Club 60, Lemhi 62, Idaed 59, and two soft red winter wheats were found satisfactory in quality. In all, some 2,500 individual plant breeder samples were given complete milling and baking, chemical, and physical dough tests during the period covered. Several thousand smaller samples were given preliminary evaluation or micro tests. Sedimentation tests were run routinely on all advanced series of bread-type wheats.

2. Drying Temperature. Wheat artificially dried at high temperatures looks plump and unshriveled. However, Kansas work showed that bushel weight of the grain was consistently reduced by drying temperatures of 120° or 160° F. and higher--depending upon initial grain moisture content. High temperatures cause the endosperm of the wheat kernel to swell and shatter, though the seedcoat does not rupture. Drying temperatures at which the baking quality of wheat is damaged depend on the moisture in the grain when it is dried. Less heat is needed to damage high-moisture wheat. Drying temperatures above 140° F. harmed the baking quality of 35-percent-moisture wheat; 20-percent-moisture wheat was dried at 180° F. without damage to baking quality. Loaf size and quality generally were not affected by grain drying temperatures up to 160° F.

3. Pre-ferment. Bread baked by 2 pre-ferment formulas indicated that strong varieties with medium to medium-long mixing times usually had better crumb grains and loaf volumes than weaker gluten varieties.

4. Round Wheat. Twelve round seeded (but not creaseless) wheats were propagated in Mexico to initiate a study on kernel shape and milling value.

5. Air Separation. In air classification studies (Ohio), significant effects were noted in protein shift due to variety, soil fertility level, or protein content, and by classification procedure. Harder wheats, higher protein, and finer machine settings resulted in lower protein shifts. The varieties Lucas, Seneca, Vermillion, and Dual had the highest protein shift, followed by Trumbull and LaPorte, Monon was lowest. The high protein soft variety B4930 was below Dual but superior to Pawnee hard wheat.

6. Biochemistry of Insect Resistance. This project was closed during the year. Major findings have been published in nine technical reports. ENT cooperated in most phases.

Negative results obtained in trying to explain resistance included protein content of tissue, ash, cellulose, trace elements, respiration activity of the plant, pH of cell sap. Hemicellulose content of the plant was correlated with resistance. Larvae were shown to secrete hemicellulase and phosphorylase. Sugar increased in the leaves of infested plants and such leaves were darker green than in uninfested plants of comparable age. A higher concentration of chlorophyll a and b was found. Carotene and xanthophyll were greater also in infested leaves. The number of chloroplasts was greater in both old and young leaves of infested plants. The sugar, allulose, or this in combination with some other component, was found in a susceptible variety but not in a highly resistant one. Sorbitol likewise was found in the susceptible variety.

Special techniques were developed during the course of the investigations, especially a hydroponic method of growing test plants and improved insect-rearing conditions to control larvae development. An unusual development was the preparation of a cinemicrograph with sound-tract giving visual and audio perception to the mechanism of feeding by the hessian fly larvae in wheat tissue.

D. Culture and Physiology

1. Coleoptile Studies. Histological studies in Washington performed on coleoptiles of three standard height varieties, two semidwarf selections, and a dwarf variety have shown that coleoptile length is related to both parenchyma cell length and number. Spinkcota and Pentad, selections with long coleoptiles, possessed coleoptile parenchyma cells which were about 10% greater in length than cells of Burt; the number of cells contributing to the coleoptile length of these two varieties was about 40% greater than cell number estimates obtained for Burt. Cell lengths of semidwarf selections C.I. 13431 and C.I. 13253 were only about 5% less than Burt but the estimated number of cells contributing to coleoptile length were 11 to 30% less than Burt and had cell number estimates that were about 8% less.

2. Emergence Rate. Gaines ranked high among semidwarf selections in rate of emergence under field conditions. Another common type semidwarf emerged more rapidly than Gaines in two field tests. Semidwarf club selections as a group were found to have slow emergence rates and developed poorly under high temperature conditions.

Work was extended to evaluate early-generation semidwarf selections for seedling emergence rate (E.R.I.) and total emergence. Minimum gene number governing the inheritance of coleoptile length in four crosses studied varied between estimates of 1 to 5. Based on observed frequency distributions, as well as heritability estimates and type of gene action indicated, both major and minor genes were involved in the inheritance of coleoptile length and seedling growth rate. The variety Nigger was found to be more suitable than Royal for use as a source of long coleoptile length in the breeding program.

Seed treatment with various combinations of B. naphthoxyacetic acid, A. naphthaleneacetic acid, maleic acid hydrazide, and A. naphthalene acetamide with gibberellic acid failed to induce either coleoptile or first leaf elongation of the semidwarf selection C.I. 13253.

The association of E.R.I. and subcrown internode length was determined to discover if rapid emerging selections set shallow crowns. The results showed that no association existed between E.R.I. and subcrown-internode length among the 54 selections studied. Some rapid emerging selections such as Baart, P.I. 178383, and Dickson 1114 form shallow crowns, yet other rapid emerging varieties such as Golden, Spinkcota, and Omar form deep crowns. Most semidwarf selections form deep crowns.

3. High Temperature Seed Dormancy. Embryo dormancy in Oregon tests appeared to be of two types: (1) post-harvest, lasting 0 to 30 days and (2) high temperature, lasting 30 or more days up to 1 year. Sharp varietal differences were noted in the first type and less precise varietal differences in the second. Both are important in early sowing of freshly harvested seed in warm soils.

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OAT AND BUCKWHEAT CULTURE
BREEDING, DISEASE, AND VARIETY EVALUATION
Crops Research Division, ARS

Problem. Most of the United States oat crop is produced under warm, humid conditions highly favorable for disease development. The major limiting factors for profitable oat production in the United States have been the heavy damage resulting from oat diseases and winterkilling. Oats, more than any other cereal crop, have suffered from a succession of severe epiphytotics of new or different diseases and have experienced several rapid and nearly complete consequent change-overs to resistant varieties. Because of the constant acute need for new disease-resistant varieties, it has not been possible to give adequate attention to improving straw strength, adaptation, nutritive value, winter hardiness, yield, grain and forage quality, etc. A widely deployed but intensive research program is essential to cope with the diverse problems affecting the oat crop.

Buckwheat has been long neglected from the standpoint of breeding for increased yield, grain quality, straw strength, disease resistance, adaptation, etc. There has been no record of any surplus of buckwheat. Information is needed about physiology and cultural methods, including effect of temperature, date and rate of sowing, fertilization, rotation, bee pollination, hormone application, etc., in order to increase the stability and efficiency of production.

USDA PROGRAM

The Department has a continuing long-term research program involving pathologists, geneticists, agronomists, and physiologists engaged in both basic and applied research in an attempt to solve the problems besetting the oat crop. The ultimate objective is to stabilize production, increase efficiency, and improve the quality of oat grain and forage wherever it is grown. Most of the work on the breeding and genetics of oats is conducted in cooperation with the State Experiment Stations at Davis, California; Tifton, Georgia; Aberdeen, Idaho; Lafayette, Indiana; Ames, Iowa; St. Paul, Minnesota; Stoneville, Mississippi; Columbia, Missouri; University Park, Pennsylvania; and College Station, Texas; and at the Plant Industry Station at Beltsville, Maryland. The World Oat Collection is maintained and

distributed from Beltsville, Maryland, with increases of the collection being made in cooperation with State Experiment Stations at Meza, Arizona, and Aberdeen, Idaho.

Oat research is being conducted under two P.L. 480 contracts. One in Poland, E21-CR-4, covers a wide range research on cereal rusts, including crown rust of oats. The second in Colombia, South America, S5-CR-2, covers oat stem rust research.

Buckwheat breeding and genetics are limited to an industry supported graduate student at University Park, Pennsylvania.

The Federal scientific effort devoted to research in this area totals 14.8 professional man-years. Of this number 6.2 is devoted to breeding and genetics; 7.0 to diseases; 1.0 to culture-physiology; and 0.6 to program leadership.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Stations in 1961 reported a total of 29.5 professional man-years divided among subheadings as follows: Breeding and genetics 19.5, diseases 4.6, variety evaluation 2.9, and culture 2.5. Oat breeding and variety testing are done to some extent in most of the 49 states where this crop is grown. The major breeding objectives are improved disease resistance, straw strength, grain quality and yield, winter hardiness in winter oats, and forage quality and yield in oats used for forage. Most states cooperate in uniform agronomic and pathologic tests coordinated by the Department. Iowa, Wisconsin, Illinois, Minnesota, Texas, and Pennsylvania are utilizing inter- and intra-specific hybridization to transfer useful genes from wild to cultivated oats. Minnesota, Iowa, and Florida are studying the role of irradiation in mutations and plant breeding. Evaluations of oat breeding methods are being conducted in California, Iowa, and Pennsylvania.

Industry and other organizations conduct only limited research on oats. Two commercial companies are engaged in breeding improved varieties of oats. Limited research on milling and the nutritional quality of new varieties is conducted by one food and feed manufacturer.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Breeding and Genetics

1. Improved Oat Varieties. Alamo-X (C.I. 7648) is an improved strain of Alamo oats developed in cooperation with the Texas Experiment Station. It was selected from the fifth generation progeny of Alamo seed that had been subjected to X-ray irradiation. Alamo-X

is superior to Alamo in being resistant to Victoria blight, culm rot, and races 216 and 290 of crown rust. It is also more winter hardy than Alamo. Alamo-X and Alamo are the only stem rust resistant oat varieties adapted to growing in Texas. They possess the AB genes, giving resistance to stem rust races 1 to 13, inclusive, and to the prevalent subrace 7A. The yield of grain and forage of Alamo-X is about equal to Alamo when disease and winterkilling are not limiting factors. Foundation seed of Alamo-X was released to certified seed growers in Texas in 1961.

Bonkee (C.I. 7563) is a new stem-rust-resistant spring-oat selection developed in cooperation with the Iowa Experiment Station in a backcrossing program where Cherokee was used as a recurrent parent in the first two generations and Bonham in the last five. The Bonham and Cherokee parent varieties possessed only the D gene, giving resistance to stem rust races 1, 2, 5, 8, 9, 10, and 11. Using the Canadian oat selection R.L. 2105 as a donor parent, the A gene was substituted for the closely and adversely linked D gene, and the B gene was added in parallel backcrossing procedures. Bonkee is resistant to races 1 to 13, inclusive, and is resistant also to the highly prevalent subrace 7A, but not to the rare virulent subraces 6A and 13A. The new variety is similar to the popular, short-strawed, early-maturing, high-test-weight Cherokee, Bonham, and Nemaha varieties, except for its superior resistance to almost all races of stem rust. The variety Bonkee is being increased by Iowa and some other North Central States for release to growers of certified seed in the spring of 1963.

Sierra (C.I. 7706), CAS 5164, is a new oat variety developed in cooperation with the California Experiment Station from a cross of a Nullisomic Selection X Kanota, with a selection of the wild Avena fatua. Thus two unique procedures were used in breeding Sierra. The female parent was a monosomic - Nullisomic X Kanota - and consequently partially sterile. This unbalanced chromosome sterility was exploited for the rather difficult hybridization operation by applying the A. fatua pollen to the flowers of the monosomic without emasculation. Sierra shatters less, lodges less, and has larger leaves and stems and denser panicles than any oat variety now grown in California. The maturity and height are similar to Ventura, and the test weight is slightly better than Indio. Grain yields have averaged 30 percent higher than Kanota, Ventura, and California Red, with the hay yields being approximately the same but more consistent.

2. Oat Breeding Methods. Results from cooperative studies with the Iowa Experiment Station indicate that a mixture of isogenic lines, homogeneous for agronomic characteristics but heterogeneous for rust reaction, should yield more under rust epiphytotic conditions than the mean of the pure lines. Furthermore, widespread growing of mixtures should slow down the ever-changing rust races and could even stabilize the race structure of rust populations. Eighteen different genes controlling resistance to crown rust are being backcrossed into 2 recurrent oat lines to produce 2 "multiline" oat varieties for crown rust resistance. The recurrent varieties being used in producing the multiline varieties are backcross derivatives of Clintland and Garry. They possess the AB genes controlling resistance to stem rust races 1 to 13, inclusive, and to the widespread subrace 7A.

3. Genetics. Five oat monosomes have been isolated and identified in cooperation with the Iowa Experiment Station. Additional monosomes have been obtained through the use of irradiation and are being identified by their breeding behavior (frequency of nullisomes) from self-pollinated monosomes, centromere location of univalents, as determined from metaphase I and anaphase I, morphology of plants, F_2 segregation data, etc.

A recessive gene "s" which causes a high degree of sterility in the diploid Avena strigosa variety Saia has been obtained by irradiation in cooperation with the Iowa Experiment Station. Plants homozygous for "s" are highly sterile. The F_2 segregations from ss X ss segregates 3 fertile to 1 sterile. Most of the few fertile seeds found on the ss genotypes appear to result from outcrosses.

Albion, an oat variety that has been the most tolerant to barley yellow dwarf virus of the hexaploid varieties tested in cooperation with the Illinois University Experiment Station, was crossed with the highly susceptible selection C.I. 7451 and the somewhat more tolerant variety Minhafer. Progenies from these crosses were studied to determine the mode of inheritance. The data obtained is not adequate to determine the precise mode of inheritance of tolerance to yellow dwarf but indicates that the tolerance in Albion is simply inherited and can be transferred by conventional breeding and testing procedures.

4. World Oat Collection. During 1961 the World Oat Collection was increased by 215 introductions from 12 foreign countries and by 151 accessions from 20 states. Field and greenhouse testing in cooperation with the Iowa Experiment Station showed that a group of new oat introductions from Russia contained several potentially useful

diploid sources of seedling resistance and at least one very promising hexaploid source of field resistance.

5. Buckwheat. Self-incompatibility represents a barrier to the development of improved buckwheat varieties by conventional breeding methods. Significant increases in seed set from incompatible combinations in field studies conducted in cooperation with the Pennsylvania State University were obtained as a result of auxin treatment during the blossoming period. Nine of 13 auxins tested were found effective when applied periodically in certain concentrations as aqueous sprays.

B. Diseases

1. Crown Rust. Crown rust, the most important disease of oats on the average, caused only trace amounts of damage in 1961. A total of 725 isolates of crown rust, distributed among 29 races from 25 states, were identified in cooperation with the Iowa Experiment Station from material collected on all varieties of oats in the United States in 1960. Races attacking Victoria were most common, whereas races attacking Landhafer were second in prevalence. Five new races, one of which attacks both Landhafer and the diploid Saia, were discovered. A total of 114 isolates, distributed among 20 races from 6 States, were identified from material collected from the alternate host *Rhamnus*. In addition to the 10 standard differential varieties, 11 supplemental differential varieties were used for testing the 725 isolates of crown rust identified. The diploid *Avena strigosa*, C.I. 3815, and the tetraploid *A. abyssinica*, P.I. 193958, were resistant to all 725 isolates.

Several strains of the wild hexaploid *A. sterilis* were found in Iowa to be resistant in the seedling stage to the virulent race 264 at low but not at moderate or high temperatures. Two new strains of the wild tetraploid *A. barbata* received from Israel were highly resistant to race 264. The two new resistant strains of *A. barbata* are apparently different from the *A. barbata* Silva strain received from Brazil and previously reported as possessing unusual resistance to crown rust. In field tests several strains of *A. sterilis* were shown to be uniformly highly resistant to crown rust races 203, 216, and 290 but to differ greatly in plant type. Additional collections of noncultivated species of oats have been received from Israel and Brazil and are now being tested with a wide range of virulent races.

The entire World Oat Collection is being screened in Iowa for tolerance to crown rust. As a result of carefully screening the first 2,000 entries of the collection, 149 entries have been selected as showing some degree of tolerance to crown rust. Ten ultra-susceptible

varieties were noted among the 2,000 entries. These ultra-susceptible varieties may have value as rust spreaders and for use as susceptible check varieties.

In an intensive varietal test of tolerance to crown rust 25 varieties were planted at 3 locations in Iowa with a different race of crown rust at each location, with 18 replications rusted and 18 replications protected from rust at each location. Preliminary data indicate that the variety Andrew was markedly tolerant to all 3 races and probably superior to the well-known Cherokee.

Seed weight appears to be a suitable measure of response to crown rust and may be superior to yield. The use of "percent decrease due to rust" was found superior to "percent increase due to fungicide," and the arc-sin transformation of data was beneficial. A seed sample size of 200 was superior to a sample size of 100 in calculating percent decrease due to rust. A split-plot experiment was shown to have some advantages but does not allow for inheritance differences in seed weight among different varieties.

2. Smut. Fifteen collections of oat smut from the Gulf Coast States were identified in cooperation with the Florida Experiment Station. They appeared to be composed of at least 5 different pathogenic groups with one group being similar to race A-20 and the other similar to race A-22. The 5 groups exhibited different pathogenicity for Red Rustproof, Victoria, and Fulghum. Collections that were pathogenic on Atlantic (a Victoria derivative) were also pathogenic on Southland. However, none of the collections that were pathogenic on Atlantic were pathogenic on Victorgrain (a Victoria derivative). Therefore, it appears that "Victoria-type" smuts exhibit considerable differential pathogenicity for non-Victoria varieties.

The complex of genes controlling pathogenicity in races of Ustilago avenae determines the degree of success in maintaining integrity of race differentiation from one season to the next. Thus far, a genetic analysis of eleven of the standard races, conducted in cooperation with the Washington Experiment Station, indicates that an adequate degree of homozygosity exists or can be established in all races for the purpose of maintaining standard race identification procedures and determining varietal reactions to individual races. Among those races that appear to be adequately homozygous for pathogenicity are 1, 2, 3, 5, 6, 14, and 20, whereas need for establishing a homozygous condition is indicated in races 7, 7b, 11, and 12.

3. Yellow Dwarf. In studies on the mechanism of aphid transmission of barley yellow dwarf virus in cooperation with the Cornell University Experiment Station, a latent period of the virus in the vector

was found following short (3 or 6 hour) acquisition feedings but not following long (48 or 72 hour) feedings. Almost as many aphids acquired virus in the short acquisition feeding periods as in the long ones, but only aphids given the long acquisition feeding were able to transmit virus within the first day after they were removed from the source plants. Although the aphid-injection technique offers a direct approach to studying the question of virus multiplication in the vector, some important technical problems must be solved before such tests can be carried out with certainty.

Cooperative studies with the Cornell University Experiment Station on the mechanism of vector specificity for the barley yellow dwarf virus revealed that the mechanism controlling specificity does not reside in the area of acquisition of the virus. One finding supporting this position was that specificity of two strains of barley yellow dwarf virus was obtained whether acquisition was by feeding or by injection. A second line of evidence was that aphids were found to acquire (by feeding) the strain of virus that they were unable to transmit. In studies on the apparent breakdown on specificity in doubly-infected plants, results were more erratic when acquisition was by injection than when acquisition was by feeding. There was some support for an explanation of the breakdown of specificity based on the possibility that the concentration of one strain of virus is greater in doubly than in singly infected plants. Another possible explanation, which is also supported indirectly by experimental results, is that the breakdown of specificity involves a different strain of virus resulting from recombination or some other phenomenon during synthesis of both strains in doubly infected plants.

In purification experiments conducted in cooperation with the Cornell University Experiment Station, a fruit juice extractor was found to be an efficient instrument for extraction of barley yellow dwarf virus from oats. A method of clarification superior to the chloroform procedure was not found. Barley yellow dwarf virus was not responsible for the visibility of zones in certain density gradient centrifugations despite its association with the zone. The virus was found to be stable to action of ribonuclease, chymotrypsin, desoxyribonuclease, trypsin, and various combinations of these enzymes. No active virus was found in preparations treated with phenol. Certain detergents prevented acquisition of barley yellow dwarf virus from partially purified preparations by aphids feeding through membranes, but active virus could be demonstrated in such preparations by use of the aphid-injection technique. The membrane assay technique was found to be as sensitive or more sensitive than the aphid-injection technique.

Transmission of an unidentified oat striate-type mosaic virus by a new leafhopper vector Graminella nigrifrons was established in cooperation with the Illinois University Experiment Station. The virus was not transmitted by the leafhopper Endria inimica, the common vector of striate mosaic virus of cereals. Investigations have been initiated to differentiate the two viruses and identify the new virus. Some evidence was obtained that the virus might be pathogenic to its vector Graminella nigrifrons.

Preliminary studies conducted in cooperation with the Illinois University Experiment Station indicate the existence of a new vector Rhopalosiphum rufiabdominalis of the barley yellow dwarf virus. Since the species is a root inhabitant and unreported for the State, it may be very important in the epidemiology of yellow dwarf.

C. Culture-Physiology

1. Winter Hardiness. The effect of seed source on the cold resistance of winter oat varieties is being investigated in cooperation with the Cornell University Experiment Station. Foundation seed of the variety Dubois was increased under irrigation at Aberdeen, Idaho, and then used for fall seeding at 11 locations in New York, Pennsylvania, Maryland, Virginia, Kentucky, Illinois, Arkansas, Missouri, and Oklahoma. Highly significant differences in cold resistance of pre-emerged seedlings were found among 11 seed sources. Analyses of the seed N, P, K, Ca, Mg, and Fe have not provided significant information on the nature of the difference in cold resistance among the seed sources. More refined chemical analyses are now being made in an attempt to determine the nature of this difference in cold resistance. Two, three, four, and five-week old plants are also being tested to determine how long in the life of the plant differences in cold resistance due to seed source prevails.

The resistance of winter oat varieties to high temperatures appears to be in the same order as their resistance to low temperatures. In studies conducted in cooperation with the Cornell University Experiment Station, relative humidity was found to significantly influence the ability of winter oats to resist injury at high temperatures. For the winter-hardy varieties, Nysel and Dubois, there was about a twofold increase in degree of injury as the relative humidity was increased from 50 to 75 percent and from 75 to 100 percent. The non-hardy Fulghum exhibited a twofold increase in injury as the relative humidity was raised from 50 to 75 percent and a 30 percent increase in injury as relative humidity was raised from 75 to 100 percent. The difference in percentage injury for the hardy and non-hardy winter oat varieties tested was smaller at 100 percent

relative humidity than at 50 percent relative humidity. Winter oats appear to be more tolerant to a combination of heat and drought stresses than to heat stress alone.

2. Host-parasite Relationship. Victorin, the specific toxin produced by Helminthosporium victoriae, appears to cause a functional disorder of the Krebs cycle in oat varieties expressing susceptible and intermediate reactions to the pathogens but has no effect on this process in resistant varieties. In studies conducted in cooperation with the Florida Experiment Station, victorin was found to cause an increase in citric and malic acids and a decrease in succinic acid. Therefore, the increased respiration reported to proceed through an ascorbic acid pathway may instead proceed through a malic dehydrogenase system to the cytochrome system. These results indicate that protein breakdown may play an important role in the increased respiration of diseased plants.

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WEED AND NEMATODE CONTROL
Crops Research Div., ARS

Problem. Weeds cause losses in crops, orchards, grazing lands, forests, water supplies, and irrigation and drainage systems. These losses can be reduced by finding more effective chemical, biological, mechanical and combination methods of weed control.

Plant-parasitic nematodes occur in all soils used for growing of crops and attack all kinds of plants grown for food, forage, fiber, feed or ornamental purposes. Severity of attack by certain fungi is increased if nematodes are present. Nematodes also have been known to be the vectors of several plant viruses. There is need for improvement in methods of controlling nematodes on cereal crops.

USDA PROGRAM

Much of the weed control research in the Department is cooperative with State Experiment Stations, other Federal agencies, industry and certain private groups; and is cross commodity in nature. The total federal weed control program involves 64.0 professional man years' effort. Of this total, 4.2 man years are specifically directed to weed control in grain crops at Mesa and Tempe, Arizona; Hays, Kansas; Stoneville, Mississippi; and Raleigh and Whiteville, North Carolina. The federal scientific effort devoted to basic and applied nematode research is 23.5 professional man-years, of which 0.6 man years are devoted to work on cereals at Auburn, Alabama; Tifton, Georgia; and Madison, Wisconsin.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

Information on the weed and nematode research for commodities by State Experiment Stations and industry is not available. For a summary statement covering all research by these agencies on weed control, see pages 240 and 241; and on nematode control, see page 276, in the Crops Research Division report.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

Weed Control

Wheat. Research at Hays, Kansas, has shown that herbicides can be used to give highly effective weed control and reduce tillage operations by 75 percent without decreasing the efficiency of moisture intake and storage. Although research must be continued for a longer period, results to date indicate that winter wheat and sorghum yields may be maintained at high levels with only minimum cultivation. When using a wheat-sorghum-summer fallow rotation it has been possible to produce the two crops and maintain weed control with herbicides during the fallow period with as few as two cultivations.

At Tempe, Arizona, a treatment was developed which effectively controls wild oat in barley or wheat. Post-emergence applications of 4-chloro-2-butynyl N-(3-chlorophenyl) carbamate (barban) at a rate of one pound per acre has greatly minimized the wild oat population without adverse effect on wheat or barley.

Research at Hays, Kansas, has shown that 2,3,6-trichlorobenzoic acid (2,3,6-TBA), as well as other chloro-benzoic acids, will control bindweed at least as well and often better than previously available chemicals. The six-year persistence of the chloro-substituted benzoic acids in the soil was related to extremely slow rates of dissipation when the chemicals penetrated to depths greater than two feet. These new compounds are relatively nonpoisonous, noncorrosive, and do not create fire hazards when used

Corn. In studies at Stoneville, Mississippi, simazine pre-emergence, 2,4-D and flame cultivation provided excellent overall weed control but the control obtained with either alone was adequate. 2,4-D gave excellent broadleaf weed control.

In experiments at Raleigh, North Carolina, a chemical has been isolated from corn plants which converts the simazine molecule to a non-toxic form. Thus, corn tolerates this herbicide while most weeds do not convert simazine to a non-toxic form and are killed. The chemical was identified as a cyclic hydroxamate with the name 2,4-dihydroxy-3-keto-7-methoxy-1,4-benzoxazine.

The exact relationship of the chemical in explaining tolerance of corn to simazine and susceptibility of weeds is being studied intensively.

Studies of amitrole activity conducted at Stoneville, Mississippi, suggested that the toxicity of the herbicide was associated with a partial blockage of normal glycolysis in corn which resulted in catabolism of proteins and amino acids in respiration.

At Whiteville, North Carolina, a number of pre-planting, pre-emergence and post-emergence treatments, cropping, and fertilization practices for controlling witchweed and growing catch and/or trap crops showed considerable promise for reducing and eradicating this parasitic weed. Sixteen herbicides appeared promising for control of witchweed in corn. 2,3,6-trichlorophenylacetic acid (fenac), which has been the best pre-planting herbicide found thus far for witchweed control, was studied extensively with respect to times and methods of application, minimum number of seasonal treatments for full-season control, and persistence of herbicide in soil. Institution of regular fertilization and crop rotation programs along with herbicides have resulted in marked witchweed control and annual increases in corn yields. At the present it appears that five years of a catch or trap crop will not completely eradicate witchweed, but crop yields have increased tremendously. Millet appeared to be superior to corn, sorghum,

field peas, and soybeans as an effective catch and/or trap crop.

Progress was made in purification and characterization of the witchweed germination stimulant(s) from corn, but further purification will be necessary for identification. In conjunction with these studies they have obtained germination of witchweed seed with 6-(2-furfuryl)aminopurine (kinetin) and certain related compounds and with two coumarin derivatives: scopoletin and 4-hydroxycoumarin.

A germination inhibitor was extracted from witchweed seed. Witchweed seed germination studies demonstrated that new seed is viable by the eighth day after flowering. Dormancy of mature seed was broken after six weeks of storage at 88° F., but more slowly at lower temperatures. Viability of seeds stored for one year under approximate field conditions decreased from 96 to 1 percent.

Further studies at Whiteville revealed the presence of a considerable number of viable witchweed seed at all levels down to a depth of five feet.

Grain Sorghum. Pre-emergence application of s-triazine herbicides provides the best treatment for seasonal weed control without sorghum injury in experiments at Hays, Kansas, and Stoneville, Mississippi. At Hays, research has shown that 2-chloro-4,6-bis(isopropylamino)-s-triazine (propazine) can be used for pre-emergence weed control in sorghum. This chemical has given more consistent weed control with less crop injury than any other chemical evaluated to date. A related herbicide, 2-chloro-4-ethylamino-6-isopropylamino-s-triazine (atrazine) has shown promise as an early post-emergence treatment. DCMA provided good control in irrigated sorghum in experiments at Tempe, Arizona.

Studies at Whiteville, North Carolina, show that there are varieties of sweet and grain sorghum that will tolerate witchweed attack far better than others. Some grain sorghums that exhibit this quality are Wheatland 288, Sumac 1712, Chicken Corn SA. 1951, Shallu Agroc 2650, Ladore, and Sharon Kafir C.L. 813. A number of sweet sorghums that appear to have some tolerance to witchweed are MER 57-6, MER 58-1, MN-6, MN-32, MN-36, and Brawley.

Other Cereal Crops. At Mesa, Arizona, studies have shown that silvex is less volatile and safer to use for weed control in barley, from the standpoint of risk of damage to other crops. Silvex should be used prior to tillering of barley and may prove valuable in areas where 2,4-D drift is a problem.

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CORN, SORGHUM AND SMALL GRAIN INSECTS
Entomology Research Division, ARS

Problem: Many species of insects cause losses amounting to millions of dollars annually to corn, sorghums, and small grains. In 1960 it was estimated that the European corn borer alone destroyed corn worth more than \$96 million. A recently expanded research program will permit an intensification of research on many of the problems associated with these insects. This program calls for research to provide more efficient insecticides that can be safely applied to the crops, that do not harm animals consuming the feed, or leave excessive residues in meat and milk. Improved cultural methods of control will be investigated, and the factors influencing insect abundance will be studied to provide current information that can be used to advise growers of the need for insect control. New approaches to control, such as sterilization techniques and sex attractants, will be explored. More attention will be given to biological-control methods such as the use of parasites, predators, and diseases. Research on varietal resistance to insects in corn, sorghums, and small grains will be intensified in cooperation with plant breeders and the nature and inheritance of such resistance determined.

USDA PROGRAM

The Department's program involves both basic and applied research directed toward developing more efficient control methods for insects attacking grain. All studies are conducted in cooperation with State Experiment Stations in the several States where research is underway. Studies on evaluating and developing varieties of grain which resist insect attack are conducted in cooperation with State and Federal agronomists and plant breeders and research on insect transmission of diseases of grain crops is in cooperation with State and Federal plant pathologists. This research includes studies on hessian fly and wheat jointworm at West Lafayette, Ind., and Manhattan, Kans.; aphids and mites attacking small grains at Stillwater, Okla., Brookings, S. D., and Tifton, Ga.; wheat stem sawfly at Minot, N. D., Brookings, S. D., and Bozeman, Mont.; corn earworm at Tifton, Ga., State College, Miss., and West Lafayette, Ind.; fall armyworm, pink scavenger caterpillar and rice weevil at State College, Miss., and Tifton, Ga.; soil insects attacking corn at Brookings, S. D., State College, Miss., and Tifton, Ga.; corn leaf aphid at Brookings, S. D.; southwestern corn borer at Stillwater, Okla., and State College, Miss.; European corn borer at Ankeny, Iowa, State College, Miss., and Wooster, Ohio; corn earworm, sorghum midge, sorghum webworm and corn leaf aphid on sorghums at Stillwater, Okla., and Tifton, Ga.; and the insect transmission of grain diseases at Manhattan, Kans., and Brookings, S.D. Research to evaluate improved equipment for

application of insecticides to grain crops is underway at Ankeny, Iowa, and Tifton, Ga., in cooperation with Federal agricultural engineers. The station at Denton, Tex., concerned with studies of the resistance of small grains to greenbug was closed in September 1961, and the manpower and funds transferred to Stillwater, Okla., to provide for needed research on sorghum insects, in cooperation with the Oklahoma Experiment Station.

Certain phases of this research are contributing to regional research project NC-20 "Factors Influencing European Corn Borer Populations". A P. L. 480 project, E8-ENT-1, "Population Dynamic Studies on Calligypona pellucida (F.) and the Nature of Injuries Caused by This and Other Leafhopper Species (Fulgoridae) on Cereals, Especially Oats and Spring Wheat" with the Agricultural Research Centre, Department of Pest Investigation, Helsinki, Finland, was activated in January 1961. Another P. L. 480 project, A10-ENT-5, "Host Plant-Vector and Host Plant-Virus Relationships of Rough Dwarf Virus of Corn and Methods for Control of the Disease" with the Hebrew University, Rehovoth, Israel, was activated in February 1962.

The Federal scientific effort devoted to research in this area totals 37.8 professional man-years. Of this number 9.5 is devoted to basic biology, physiology, and nutrition; 4.6 to insecticidal and cultural control; 3.0 to insecticide residue determinations; 3.0 to biological control; 2.3 to insect sterility, attractants and other new approaches to control; .5 to evaluation of equipment for insect detection and control; 11.9 to varietal evaluation for insect resistance; 1.6 to insect vectors of diseases; and 1.4 to program leadership.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Stations in 1961 reported a total of 27.1 professional man-years divided among subheadings as follows: basic biology, physiology, and nutrition 10.3, insecticidal and cultural control 9.0, insecticide residues .6, biological control 1.4, insect sterility, attractants, and other new approaches to control .2, evaluation of equipment for insect detection and control .7, varietal evaluation for insect resistance 3.5, and insect vectors of diseases 1.7. Iowa, Kansas, Minnesota, Missouri, Nebraska, Ohio, and South Dakota are conducting cooperative studies under Regional Project NC-20 on factors influencing European corn borer populations. The biology, ecology, and systematic relationship of the complex of corn rootworms in the Corn Belt is being worked on to clarify confusion in species and habits. Insecticides are being tested for control of the more important grain insects. A limited amount of work is underway on the use of bacteria and fungi as natural control agents for grain insects. The use of various lights as a means of attracting corn borers and earworms is being explored for detection purposes. Several State Experiment Stations have work in progress on the development of crop varieties resistant to such insects as

the European corn borer, rice weevil, greenbug and hessian fly. Transmission studies are being made to identify insect vectors of aster yellows and barley yellow-dwarf diseases of barley.

Industry and other organizations. Several chemical companies have field testing programs on insecticides for control of insect pests of corn, sorghums, and small grains. Estimated annual expenditures are equivalent to approximately 10 professional man-years. Producers of grain cooperate with the Department and State Experiment Stations in providing fields that may be used for insecticidal tests. A number of hybrid seed corn companies employ an entomologist to assist in developing corn hybrids resistant to insects. Their estimated annual expenditures are equivalent to approximately 3 professional man-years.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Basic Biology, Physiology, and Nutrition

1. Corn Insects. Long-range population studies on European corn borer at Ankeny, Iowa, indicated an increase of overwintering borers from 162 per acre in 1960 to over 5,000 per acre in 1962. In 1961 the first-brood population was about the same as the overwintering population, but the fall population was 5.4 times greater than that of the first brood. Resistance of corn hybrids to the corn borer was more effective in reducing first brood populations than was date of planting. However, date of planting was more effective in reducing second brood populations than was hybrid resistance.

The corn earworm caused an estimated 2.4% loss to corn in Georgia in 1961, according to studies made at Tifton, Ga. Eighty-one percent of the fields surveyed in the State were infested by rice weevil, 95% by the pink scavenger caterpillar and 30% by the fall armyworm. Damage by the corn earworm was .72% in Mississippi, 1.5 in Tennessee, 1.6 in Kentucky and .72 in Illinois in the areas surveyed. Corn earworm larvae penetrated deeper into the ears of a resistant single cross than into those of a susceptible single cross. The total number of larvae reaching the full-grown stage was greater on the susceptible cross.

At Stillwater, Okla., when corn was machine-harvested, girdling by the southwestern corn borer caused losses up to 39%, depending upon the percentage of infestation, time of planting, and environmental conditions.

2. Small Grain and Sorghum Insects. Since 1960 hessian fly infestations have decreased in wheat areas East of the Mississippi River and increased in most of the areas West of the River. The average infestation of susceptible wheat varieties in 13 Central Kansas counties was 16% whereas that of the resistant varieties was only 1%.

In biochemical studies of hessian fly larvae grown on semi-artificial media, the juices from resistant selections of wheat contained substances toxic to the larvae. The juices from susceptible varieties did not have this effect and permitted larval development. Radiological studies indicated that feeding by hessian fly larvae occurred on resistant wheats for a maximum of 2 days and on susceptible wheats for a maximum of 15 days.

In studies at Stillwater, Okla., the first and second instar larvae of the corn earworm preferred the flowering stage of sorghum kernels, and the third, fourth, fifth and sixth instar larvae preferred the milk stage. The average consumption of sorghum by corn earworm larvae under insectary conditions, in grams per instar was as follows: First instar 0.0853; second, 0.0759; third, 0.2981; fourth, 0.3533; fifth, 0.8330; and sixth, 3.1397. The average total consumption during the entire larval period was 4.7853 grams per larva.

Winter and spring varieties of wheat reacted very similarly to wheat curl mite development at Manhattan, Kans., when the winter wheat was vernalized or when light and temperature conditions were such that the fruiting growth of spring wheat was delayed or suppressed. Mites reproduced very rapidly on the vegetative stages of both winter and spring wheats, but their numbers declined as the plants began to send up fruiting culms. This decline continued until just prior to maturity when there was a short period of very rapid mite reproduction.

Studies on the leafhopper Calligypona pellucida in Finland under P.L. 480 project E8-ENT-1 disclosed that the insect overwinters in timothy fields and migrates, largely as winged adults, to grain fields in June. The migrations were principally to oats and spring wheat. The most important natural enemies of the leafhopper were two species of Hymenoptera which destroyed large numbers of eggs. About 0.7% of the nymphs and 20.0% of the adults were parasitized by other species of Hymenoptera. Fall plowing also destroyed large numbers of nymphs.

B. Insecticidal and Cultural Control

1. Corn Insects. In field tests one application of Telodrin (SD-4402) at .2 pound per acre applied in granules or a spray gave satisfactory control of the European corn borer at Ankeny, Iowa. For second brood corn borer control, 25 pounds per acre of 1% endrin granules gave better control than 6.25 pounds of 4% endrin granules, and granules of 40/50 mesh size gave better control than granules of other sizes.

Thirteen insecticides were tested for control of the earworm at State College, Miss. Bayer 44646 alone gave control equal to DDT and Sevin. Tung oil did not increase control when added to sprays containing DDT or Sevin.

Three applications of endrin at 2 pounds per acre and of Sevin at 1.5 pounds reduced southwestern corn borer infestations from 52.8 to 4.8 and 8.0%, respectively. DDT at 2 pounds per acre failed to reduce the infestation.

Effective control for the lesser cornstalk borer on sorghum and corn in Mississippi was obtained by applying phorate granules at the rate of one pound of phorate per acre, or aldrin as a spray or granules at one or two pounds of aldrin per acre, in an 8-10 inch band along the drill row at time of planting.

2. Small Grain and Sorghum Insects. A search for more effective insecticides and better methods of applying them for wheat stem sawfly control has been continued at Minot, N. Dak. The best control obtained in 1961 was 51% with heptachlor as a furrow application at 1 pound per acre.

At Stillwater, Okla., the influence of low temperatures on effectiveness of insecticides for controlling the greenbug was studied at temperatures of 35-60° F. The organic phosphates tested gave good initial control throughout this range of temperatures, but Phosdrin gave poor residual effectiveness at temperatures above 60° F.

The application of nitrogen to wheat, in addition to increasing plant growth, usually caused an increase in the population of apple grain aphids and English grain aphids. However, the type of formulation of nitrogen and time of application had some effect on plant growth and aphid population. Ammonia nitrate applied both in spray and solid form in the spring produced the least plant growth and lowest aphid populations. Fall application resulted in the largest plants and highest aphid populations. Cultural practices of wheat such as stubble mulching and crop rotation had no apparent effect on populations of aphids which moved into the crop after the plants emerged.

C. Insecticide Residue Determinations

1. Residues on Corn. Kernels from corn in plots treated with Dylox, diazinon, Sevin, and heptachlor epoxide contained no residue in detectable amounts in samples collected 1 day after treatment. EPN was applied at .5 pound per acre within 7 days of harvest to corn without leaving more than 0.2 p.p.m. residue on the stalks.

When Telodrin (SD-4402) was applied to dent corn at 0.1 pound per acre for first-generation corn borer control, the residues were less than 0.5 p.p.m., 68 days after treatment. When the dosage was increased to 0.2 pound of Telodrin per acre, the residues 5 days after treatment averaged 1.2 p.p.m. and declined to 0.6 p.p.m. or less 59 days after treatment. Granular applications of the insecticide applied for second-generation borer control left residues of

1.0 p.p.m. from a 0.1 pound-per-acre dosage and 0.8 p.p.m. from a 0.2 pound-per-acre dosage 43 days after application.

Spray and granular EPN were applied at 0.25 pound per acre to corn plots on July 6 and 11. Parathion spray and granules were applied to other plots at 0.5 pound of parathion per acre. Husk-cob (silage) samples taken at intervals were analyzed at Vincennes, Indiana, when fresh and after fermentation. With EPN the fermented samples averaged about 0.1 p.p.m. higher in residue than unfermented samples, whereas the opposite was true with parathion. The corn stalks carried greater residues of both EPN and parathion than the other plant parts. Sprays deposited greater residues of both EPN and parathion on corn plants than did granules. Corn kernels contained no more than 0.1 p.p.m. of either parathion or EPN, even when samples were collected 1 day after treatment.

Residues in corn resulting from treatment with several insecticides were investigated at Vincennes. In plots treated with 0.25 pound of endrin per acre as a spray or granules, the greatest amount of residue was retained by the stalks of the corn plants, which contained as much as 0.15 p.p.m. of endrin 38 days after treatment. The husk-cob waste from these plots contained 0.1 to 0.5 p.p.m. of endrin 1 to 7 days after treatment and less than 0.1 p.p.m. 38 days after treatment. The corn kernels were free of endrin.

In another study, EPN was applied to corn at 0.5 pound per acre in granular form to determine the rate of loss of residue from the plants and to see whether the EPN would undergo any decomposition in the fermentation of corn silage. Applications were made on July 12 and 20. Samples of the plants collected at intervals were chopped, mixed, and aliquots taken for analysis and for sealing in polyethylene bags to ferment. Immediately after treatment the plants contained 5.5 to 7.8 p.p.m. of EPN. After fermentation the residues decreased to 3.2 to 5.9 p.p.m. EPN was lost rapidly from the plants, dropping to about 0.1 p.p.m. in one week. Silage made from corn cut one week after treatment contained 0.1 to 0.2 p.p.m. of EPN.

Analysis of corn plants treated from 1 to 4 times with endosulfan (Thiodan) spray or granules at 1 pound per acre showed the greatest residue on the stalk, about 5 p.p.m. of endosulfan, one day after spraying and 1.5 p.p.m. after the granular treatment. Husk and cob contained about 0.8 p.p.m.; no residue was found in the kernels. Delnav residues on corn plants from a single spray of 1 pound per acre averaged 9.2 p.p.m. 24 hours after application. In plots treated 3 times with Sevin at the rate of 1 pound per acre as spray or granules, corn sampled 7 days after the last application had 0.4 p.p.m. of Sevin in the stalks from the granular treatment and none from the spray. The husk and cob contained about 0.3 p.p.m. of Sevin and the kernels none.

Granular formulations of diazinon, Sevin, or phorate were applied to field corn at rates of 1 and 2 pounds of toxicant per acre. Less than 0.1 p.p.m. of diazinon remained in the corn plants 58 days after treatment. Sevin residues were 3.2 and 7.7 p.p.m. five days after treatment with the 1 and 2 pound dosages, respectively. Ninety days later the Sevin residues were less than 0.1 p.p.m. Phorate residues about 2 months after treatment were less than 0.1 p.p.m. for the 1-pound dosage and about 0.1 p.p.m. for the 2-pound dosage. Granular formulations containing 5% and 20% BHC were applied to corn at 1 pound of BHC per acre. The residues 5 days later averaged 1.21 p.p.m. of BHC from the 20% formulation and 3.57 p.p.m. from the 5% formulation. The difference is attributed to the greater bulk of the formulation containing 5% BHC.

Residues in corn plants resulting from application of Dylox granules and Dylox sprays were estimated from the organic phosphorus residues present in the plants. When granules were applied at the rate of 1 pound of Dylox per acre, the residues averaged 1.1 p.p.m. of Dylox 6 days after treatment and 0.1 p.p.m. about 2-months after treatment.

2. Residues on Wheat. Granular heptachlor was added to the drill row at the rates of 1/4 to 2.0 pounds of toxicant per acre when wheat was planted. No measurable heptachlor or heptachlor epoxide was found in the threshed grain from the plots receiving these treatments.

D. Biological Control

1. Corn Insects. Studies on biological control of the European corn borer were conducted at Ankeny, Iowa. Parasitism of the insect by exotic parasites increased slightly in 1961 over the previous year. Ohio, Iowa, Pennsylvania, New Jersey, and Maryland had the highest percent parasitism with 15, 14.7, 13.6, 11, and 10%, respectively. Macrocentrus gifuensis was the most important parasite in Iowa, Maryland, New Jersey, and Pennsylvania. Harogenes punctorius was recovered from 7 of the 15 States, being most abundant in Indiana and Ohio. A native parasite Labrorychus prismaticus, which emerges from the pupal stage of the borer, appeared in numbers for the first time in Iowa. A method has been developed for eliminating Perezia pyraustae in artificially-reared borers in the laboratory. This will provide a means to measure more accurately the effects of the protozoan on larval mortalities, growth and fecundity. When stress conditions are imposed on corn borer larvae infected with this protozoan, the larvae often fail to survive. Such stress conditions might be extremes of temperatures or resistant lines of corn.

Bacillus thuringiensis in granular form controlled first-brood borers as well as the standard DDT but did not control second-brood borers. When applied to the upper parts of corn plants as a spray the bacteria gave poorer control of the fall armyworm than DDT or Sevin, but gave almost as good control as Sevin when the spray was forced deeply into the whorls.

E. Insect Sterility, Attractants, and Other New Approaches to Control

1. Corn Insects. At Ankeny, Iowa, a study evaluating the use of X-rays in the sterilization of corn borer moths showed (1) exposures of 1-day old male moths to 32,000 roentgens resulted in 1% hatch in eggs laid by untreated females mated with the treated males and (2) exposure of pupae to X-rays resulted in a reduction in the percent of egg hatch as the dose increased. Chemicals extracted from female moths of the European corn borer were not attractive to the males.

2. Small Grain Insects. Ethanol extracts of hessian fly female adults attracted male adults whereas water extracts had no effect in work at West Lafayette, Ind. Tests designed to determine if an olfactory sex attractant was involved in the sawfly mating process were negative.

F. Evaluation of Equipment for Insect Detection and Control

1. Corn Insects. Since granular formulations vary in density, it has been difficult to make easy calibrations of the discharge rate from granular applicators. Cooperation has been given the agricultural engineers at Ankeny, Iowa, in their development of a simple apparatus whereby correction factors for different densities can be compensated for and the pounds of granules per acre for a specified row width can be determined directly from a scale.

G. Varietal Evaluation for Insect Resistance

1. Corn Insects. Investigations on strains of corn resistant to the European corn borer continued at Ankeny, Iowa, and Wooster, Ohio. A program to improve the inbred line WF 9 for resistance to first-brood infestation of the corn borer and at the same time retain its highly desirable qualities as a seedparent, has been underway since 1950. A group of WF 9 recovered lines produced by recurrent selection procedures continue to show a very satisfactory level of resistance to leaf feeding of first-brood borers. Several resistant lines developed during the past 10 years have been given permanent Iowa B designations. Permanent designations have also been assigned to five lines which originated in the cooperative USDA-Ohio corn resistance program at Toledo and Wooster, Ohio. Oh 501 was derived from (W24 X B2); Oh 502 and Oh 503 are sister

lines derived from an Ohio 24-line synthetic variety; and Oh 504 and Oh 505 are AF 9 recoveries derived from (41.2504 B x WF 9)s. These lines have indicated a good degree of resistance to corn borer, leaf blight, and stalk rot.

Genes that induce mutation are being utilized to induce borer resistance in four corn borer susceptible lines (WF 9, Oh 07, Oh 04, and Oh 28) which have superior agronomic characteristics. Several hundred Oh 28-mutable system plants from these tests had a low level of larval establishment from an artificial infestation.

Experimental dent corn hybrids and crosses, and commercial hybrids, were evaluated for corn earworm resistance in Georgia, Mississippi, Louisiana and Texas. Some of the consistently better corn earworm resistant hybrids are Miss. 6133, Miss. 6131, Pfister 653W, Coker 71, and Dixie 18. Single-cross and three-way cross tests show that inbreds L501, L503, F44 and F6 are good sources of earworm resistant germ plasm. Resistance, especially in L501 and L503, is dominant in the single cross progenies.

No outstanding resistance was observed in dent corn to the pink scavenger caterpillar or rice weevil but there was some evidence that a long, tight husk reduced the damage caused by these insects.

2. Small Grain and Sorghum Insects. Cooperative research with wheat breeders in several States was continued to develop hessian fly resistant wheats under leadership at West Lafayette, Ind. Fifteen fly resistant varieties are now recommended or grown in 31 States. The fly-resistant wheats, Ace, Georgia 1123, and Lathrop were released by Arkansas, Georgia and Wisconsin, respectively, in 1961. Ace and Georgia 1123 have the W38 resistance; and Lathrop, a spring wheat, carries the P.I. 94587 resistance. Many other selections in the wheat breeding program in Kansas, Indiana and other States have a high degree of resistance to one or more hessian fly races.

In a continuation of monogenic studies to locate the chromosomes responsible for the W38, P.I. 94587 and Ribeiro resistance to hessian fly, chromosome 1C was tentatively identified as responsible for the single gene resistance of a Purdue P.I. 94587 derivative.

Thirty-two Purdue barley selections having the Nile and Delta resistance reacted resistant or heterozygous to Races A and D of the hessian fly. F_1 crosses between six resistant barleys were made to determine if they differed from one another genetically in respect to fly resistance. The Besert and Decatur backcrosses reacted resistant when based on plant reactions. When based only on the absence of viable larvae regardless of plant reaction, many of the lines were resistant.

Studies on wheat stem sawfly resistance were conducted at Minot, N. Dak., and Bozeman, Mont., in cooperation with wheat breeders of the Cereal Crops Research Branch, Crops Research Division, and entomologists and plant breeders of the North Dakota and Montana Agricultural Experiment Stations and the Science Service Laboratories of the Canada Department of Agriculture.

In the International sawfly nurseries several selections were more resistant than the Rescue check. Sawtana (Rescue x 1831, B51-9), a product of the breeding program in Montana, has good sawfly-resistance and agronomic qualifications and was released as a commercial variety to Montana growers in 1961. Another, II-50-17 x51-2688, 57-134, from the North Dakota program, has good resistance to sawfly, leaf and stem rust. It also has good agronomic characteristics as well as good milling and baking quality, and is being considered for release.

Studies on the development of greenbug-resistant varieties of wheat have been in progress for several years at Stillwater, Okla. The resistant Dickinson Sel. 28-A has been crossed successfully with Ponca, a high quality wheat, and many desirable agronomic characteristics have been transferred to the selections while maintaining a high degree of greenbug resistance. When some F₇ selections of the cross were compared with Ponca under heavy greenbug infestations, about 2/3 of the Ponca plants were killed and the yield was only 1.4 bushels per acre. None of the plants of the greenbug-resistant F₇ selections were killed and yields ranged from 12.1 to 17.7 bushels per acre.

Eight of 121 barley lines tested for resistance to the corn leaf aphid showed a high degree of resistance. Three of these, all Rogers x Kearney lines, are also resistant to greenbugs. Since the other corn leaf aphid resistant lines are susceptible to greenbugs, it is assumed that a different gene is responsible for resistance to the two aphids.

H. Insect Vectors of Diseases

1. Wheat Insects. Studies were continued at Manhattan, Kans., on the seasonal development of the wheat curl mite and wheat streak mosaic which it transmits, in cooperation with plant pathologists. There was a widespread infestation of the mite in most wheat fields in Kansas. However, there was little volunteer wheat and most of the population died when the crop ripened. Ten common grasses were studied in their relation to the endemic populations of the mite. Five were very susceptible to both mites and mosaic, two were susceptible to mites and not mosaic, and three although susceptible to mosaic had variable ability to sustain mite colonies. These

grasses, although important in sustaining a continuous mite population in an area, did not produce sufficient mites to cause a serious epiphytotic of the disease. The survey work of the past several years has shown conclusively that extensive early growth of volunteer wheat is necessary to cause serious spread of the disease.

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EQUIPMENT AND STRUCTURES FOR PRODUCTION,
FARM HANDLING AND STORAGE
Agricultural Engineering Research Division, ARS

Problem. Better methods, techniques, equipment and structures for use on the farm for producing, harvesting, storing and the initial preparation of grain for market are needed to increase efficiency in the use of labor and equipment, preserve quality and prevent spoilage and damage from mechanical handling and insects.

USDA PROGRAM

The Department has a continuing long-term program involving agricultural engineers engaged in both basic and applied research on the engineering phases of grain production, handling and storage. The work is carried on at Beltsville, Maryland; Experiment and Tifton, Georgia; Ames, Iowa; and Manhattan, Kansas, in cooperation with Agricultural Experiment Stations. It involves 10.9 professional federal man-years annually.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Stations in 1961 reported 10.2 professional man-years engaged in agricultural engineering research related to grains, of which 2.4 man-years were devoted to problems of crop harvesting and handling operations and equipment; 4.9 to grain drying, 2.4 to buildings for farm storage of grain and 0.5 to study of electromagnetic equipment to control insects in farm-stored grain.

Both large and small manufacturers of farm equipment and chemicals are developing and testing materials and equipment suitable for use in planting, harvesting, drying and protecting grain crops. Since industry relies primarily on public agencies for basic research, considerable interest, encouragement and cooperation is given by industry. Farmers and organizations furnish crops, equipment, and facilities for experimental use.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

Fertilizer Placement & Distribution Equipment. Tests were conducted on small grains in Michigan and Texas, and corn in Maryland and Nebraska. The experiments conducted involved the use of 9 special machines designed for this purpose. The yields of winter wheat in Indiana in 1960 gave significant differences where fertilizer was placed in continuous bands 1" below the seed with 900# 5-20-20 fertilizer per acre when compared with the common method (contact w/seed, 31 - placement, 36 bu/A). Differences were also secured on the 600# and 300# rates, although they were not statistically significant.

In 1961, the establishment of field crops and vegetables were put in. Seventeen experiments were handled out of the Beltsville Station, three by the Southeastern Station and eight by the Southwestern Station. Some of the notable results in 1961 included response on fertilizer placement on winter wheat. In cooperation with Michigan State University, a field experiment with the Investigation's special drill for research on winter wheat showed an increase over conventional drilling in 7" rows in contact with fertilizer of 15% greater yield (37.5 to 43.3 bu/A) by placing the fertilizer in a continuous band to the side and below the seed row (about 1" X 1"), or a 19% greater yield (37.5 to 44.8 bu/A) by drilling in 4" rows (instead of 7" rows); or the combination of the above two practices gave a crop yield increase of 37% (37.5 to 51.3 bu/A - fertilizer contact with seed in 7" drill rows vs. fertilizer side placed to 4" drill rows).

Fertilizer placement studies were made on corn in 1960 and 1961. In conventional planting, the initial fertilizer containing 1/3 of the nitrogen is applied at planting time 2" to one side and 2" below the seed, and the remaining 2/3 of the nitrogen applied as a side dressing 8" to the side of the row, 2 to 3" deep. Results of two years' studies have shown that higher yields can be obtained by using either of the following treatments: (1) Same initial placement as conventional but with the side dressing placed 8" deep in the middle, or (2) all fertilizer applied at the time of planting placed 2" to the side and 2" below the seed.

Insect Control in Grain. Work was done on the development and evaluation of equipment for control of the corn borer in Iowa. Corn borer infestation in 1960 was extremely low, and the insecticide and application equipment investigations were curtailed. Emphasis was placed on new materials that would be effective without leaving objectionable residues on corn stalks and ensilage and on studies of distribution of granules with application equipment. Results of residues studies indicate that EPN can be applied three times at rates of .55 lb. per acre if a 15-day waiting period prior to harvest of sweet corn is used without exceeding the allowable 1.0 p.p.m. in the canning factory waste. The granular formulations resulted in lower residues than equivalent amounts applied in sprays. Equipment was developed and a method devised to measure the amount of granular material intercepted by the corn plant during applications of granular insecticides for corn borer control. Results of tests indicate that corn plants at 30-inch natural height intercept less than 30 percent of the total granules applied. Corn borer control equipment field experiments in Ohio were not completed during 1960 because of the low borer infestations in Ohio where tests were planned.

In Iowa during 1961 the development and evaluation of equipment for control of corn borer and screening tests of both liquid and granular formulations of new insecticides, were continued. One of the more promising new chemicals for controlling corn borer larvae in field corn

in 1961 was Telodrin applied at 0.2 lb. per acre. The liquid and granular chemicals tested caused little or no problems with application equipment. Studies on the evaluation of insecticide applications for borer control on corn yields show that greatest yield reductions occurred when insecticide applications were delayed.

Studies were continued to determine the most effective granular size for borer control. In 1961 the 40/50 mesh sizes were most effective for second brood borer control. Previous work has shown very little difference within the 15/60 mesh size ranges for first brood control. Granular mesh sizes below 60 were difficult to meter and distribute. Differences in borer control between the larger and smaller mesh sizes were insignificant. These results indicate little or no practical value for the design and development of equipment for applying fine mesh granules.

Field experiments on corn borer control with ground machines at Wooster, Ohio, were abandoned during 1961 because borer infestations were too low to conduct tests. The corn borer hydraulic spray equipment was used in corn earworm field experiments on sweet corn. The earworm populations were heavy, often several worms were in one ear. Six spray applications were made within a fourteen day period starting with 1 percent of the ear shoots showing silk and ending after 100 percent silking. Two wide angle, hollow cone nozzles per row, one on each side, gave good coverage of the silk zone when applying 35 gallons per acre at 40 psi. The most effective insecticide was Sevin which gave 96% clean ears. A combination of DDT and malathion gave 93% and DDT alone 85% clean ears.

Weed Control in Corn and Soybeans. Studies were made in Iowa in 1960 and 1961 on the early application of herbicides to corn to eliminate the need for soil manipulation for seedbed preparation, and if possible through the growing season. Atrazine, Simazine, and 2,4-D sprays were applied in early April on fall-plowed, spring-plowed, and unplowed cornstalk ground. Various degrees of secondary tillage ranging from none to several diskings and harrowings were performed on the sprayed plots. Atrazine and Simazine gave full season weed control, and 2,4-D up to planting time. Results indicate that it is possible to grow corn profitably without any seedbed preparation if the weeds are controlled chemically. The previous crop residue on the ground caused some planting problems.

In Missouri in 1960, a pre-emergence treatment of 20 lbs. per acre of Na PCP plus cultivations as needed was the best combination of mechanical and chemical weed control. Results based on corn yield indicate no significant difference between liquid and granular 2,4-D when applied at 1-1/2 lb./A. However, when applied at 3 lb./A the liquid formulation caused damage to the corn while the granular treatment did not affect the corn yield.

Studies were conducted in Iowa in 1961 to evaluate practices and types of cultivating equipment for controlling weeds in corn fields. Harrowing after planting did not materially improve weed control, but caused a slight reduction in stand, and reduced yields where sweep cultivations only were used. Three sweep cultivations were superior to two in terms of yields, stands, and weed control. The differences between two and three sweep cultivations were not significant when used in combination with shallow cultivations performed with rotary hoes, weeders, and dragging hoes. The results of this and previous studies indicate that the cost of weed control on corn can be reduced by using combinations of shallow and sweep type cultivators.

Studies of the effect of three tillage methods on three weed control methods were conducted in 1961 at one location in Missouri. Corn stands and yields were significantly lower and weed yields significantly higher on strip-tilled plots than in plots prepared by either the plow-plant or conventional methods. Corn yields were significantly higher and weed yields lowest in plots receiving atrazine as a pre-emergence weed control treatment. These results indicate that a full season chemical weed control treatment is essential during seasons when weather conditions prohibit adequate mechanical cultivation and that the roughness of the soil surface due to tillage methods had no effect on the activity of the herbicide treatments.

Studies were made (in Missouri) in 1961 to determine the effect of directed post-emergence applications of dalapon and 2,4-D on corn. Treatments of dalapon at 4 lbs/A and a mixture of 2,4-D (1/2 lb/A) and dalapon (4 lbs/A) were applied to corn with exposure to the corn stalk from 0 to 5 inches. Leaf lifters were designed to raise the corn leaves while the stalk and weeds were sprayed. Results indicate no reduction in corn yield when 5 inches of stalk was sprayed with dalapon at 4 lbs/A. This treatment has possibilities where heavy infestations of grass make it necessary to use a nonselective herbicide such as dalapon.

Studies were continued in Iowa in 1961 to evaluate various granular herbicide formulations and to develop methods and equipment for accurate and efficient application. Pre-emergence studies on corn continued to show that granules were as effective as liquids. Studies were made to determine the number of granules required per unit area of soil surface for effective weed control. Using 2,4-D ester granules of various sizes showed that 0.3 granules per square inch were as effective as 5.2 granules per square inch when measured in terms of number of surviving weeds in mid-June.

Studies of the metering characteristics of granular herbicides were continued in 1961 with tests of some of the common granular applicators. Results indicate that the fine granules tend to move to the bottom and the coarse ones to the top of the hopper as the applicator is operated.

With most of the commercial applicators, the amount of material discharged from the applicator did not vary directly with the speed of the agitator so that relatively constant field speeds are required for accurate metering. An error of about 10% in discharge rate due to inaccuracy of the metering device was common with the granular applicators used. An experimental screw type metering device was tested and found to vary in feed rate directly with the screw speed. However, the discharge was pulsating rather than a desirable steady flow.

A nozzle test stand was developed in 1960 so that spray nozzles could be accurately calibrated. Results from calibration studies show that a 10% difference in discharge rate between nozzles of the same size from the same manufacturer is not uncommon.

Basic studies of rotary hoe performance were continued at Minnesota. (The rotary hoe is used for cultivation and weed control.) Values of vertical and horizontal operating forces on rotary hoe teeth were computed using certain assumed relationships between displacement and forces and found to agree well with measured values of these forces obtained from strain gage dynamometers. Operating forces required to maintain a constant operating speed and depth of penetration were found to vary considerably with the design of the tooth. There is no consistent relationship between the magnitude of vertical and horizontal operating forces and the operating characteristics of rotary hoes having different tooth configurations as measured by the quantity of soil disturbed. The quantity of soil disturbed was found to be an indicator of the effectiveness of the rotary hoe for cultivation and weed control and was found to be greatly influenced by tooth configuration.

Corn Harvesting Equipment. At Experiment, Georgia, the results of two years of trials show that for the Southeast, if corn is harvested at a moisture content of 20 to 22 percent, highest efficiencies will be obtained and losses will be lower. This confirms results obtained previously in other corn areas. While preliminary studies also indicate a minimum of kernel damage by the harvester at this same moisture range, the extent of damage is more dependent on machine adjustment.

At Clemson, South Carolina, the simple low-cost corn header attachment for a combine developed in 1960 was refined and field tested on both pull-type and self-propelled type combines. The higher capacity of the self-propelled machine resulted in higher ground speeds and lower cleaning losses. Operating at 5.8 miles per hour, the unit performed well in 100-bushel-per-acre fields of corn. The ear corn loss averaged 3.5 percent. The unit was also tested in grain sorghum.

Drying of Grain. With the help of the Weather Bureau, maps of the United States have been prepared showing the average wet bulb temperature and average wet bulb depression for each month of the year. The

available data is now in a form that can be used for grain drier design and operation. The maps are completed but not yet published. It is expected that they will be published by ASAE. The maps also show the standard deviations so that the designer can estimate the probable deviation from the average. The data were from about 200 Weather Bureau Stations and cover about ten years of observations. Records for earlier years are too fragmentary to be useable for this purpose.

Tests on the counterflow drying of grain were completed. They included tests on corn, oats, wheat, and grain sorghum. In a counterflow process each kernel leaves the drier when it reaches the desired final moisture as contrasted with a typical batch drier in which some kernels are overdried and some underdried when the average moisture content has reached the desired level. In counterflow drying, all of the grain reaches the same temperature. For these reasons higher air temperatures may be used before heat damage or overdrying damage occurs than in a conventional drier. Grain sorghum germinated after drying at air temperatures of 150° to 160° F. whereas with a conventional drier the highest temperature that may be used safely is about 110° F. Additional germination tests on sorghum and corn dried in a counterflow drier have been completed. These results show conclusively that the rate of moisture removal by itself is not the cause of loss in germination. In counterflow drying the rate of drying of each kernel is almost constant throughout the drying period. Germination is lost if the conditions are such that this constant rate of moisture loss is continued too long.

Reabsorption of moisture by dried grain. Preliminary studies have shown that expansion from reabsorption of moisture by dried grain resulted in pressures which burst a wooden test bin. In a steel bin test, slippage of the bin sheets at lap joints allowed the bin to absorb the increased pressure without other failure. Additional tests are needed to determine the life of steel bins subjected to repeated rewetting tests. With absorption of moisture in the grain, the vertical pressure on the wall reverses direction and the grain tends to lift the wall. The depth of the wetting zone in the grain in such a bin is far greater than the corresponding drying zone in grain which is being dried.

Time limits on in-storage drying of grain. Study was continued on the rate of deterioration of grain in model drying bins by measuring the rate of CO₂ production. Mechanical damage to the grain increases the rate of spoilage greatly. The number of variables and the limited season during which naturally wet grain is available makes the accumulation of data very slow. A new technique by which a much larger number of tests may be made simultaneously has now been adopted. It consists of measuring the accumulation of CO₂ rather than the rate of production and reducing the size of the model bins so that tests can be run in laboratory flasks. It appears that the difficulties in making such small samples duplicate full scale drying bins have been

solved. Current studies in 48 such bins or samples have been completed. Corn at six temperatures and four moisture contents was tested. It appears from the results that it may be possible to distinguish between the respiration of the grain itself and that of the micro-organisms infecting it, and that these two sources of deterioration are influenced differently by changes in temperature or moisture. It was found that with corn moisture content at 22 percent or above, the deterioration rate could be measured with satisfactory accuracy.

Crop Storage Structures. At Ames, Iowa, samples of high moisture corn from sealed storage having various degrees of spoilage were tested by the Animal Husbandry Division for protein nutritive value. Little difference was observed between "good" and "poor" samples of wet stored grain in rat feeding tests. Four small silos (6'x16') were set up for measuring the rate of leakage of air, and measuring the effect of controlled air leakage on the quality of the stored corn. These tests will give better data on the relation between air penetration and quality.

Six typical plans for storage structures or structures for storage combined with some other activity developed at Beltsville, for the Cooperative Farm Building Plan Exchange include a pole type corn crib (35 bushel per foot of length), a hay shed (2 1/2 tons baled hay per foot of length), a potato storage (60,000 cwt), a drying and storage shed (25' x 45'), a small storm and storage cellar, and a small storage and fallout shelter.

Insect Control in Grain. Studies in prior years have established that brief exposures to radiofrequency (r-f) electric fields can kill insects in infested grain without damaging the germination of the grain. Egg and larval stages have been more resistant to such control, but treatments of about 5 seconds, which produce grain temperatures in the range from 140° to 150°F., have been sufficient to kill all developmental stages of most insects tried in laboratory tests. Results show that somewhat longer exposures are required to obtain complete control of some dermestid larvae. Treatments using high electric field intensities were more efficient than low intensities in killing dermestid larvae and granary weevil. Preliminary work indicated that r-f treatments providing insect control also may reduce activity of grain storage fungi. Studies of the physiological effects of r-f treatment on American roaches using chemical analyses have revealed differences between the nerve tissues of untreated insects and those receiving sublethal exposure.

Basic Studies of Radiation Treatment for Grain. The water sorption of grain sorghum seed was increased by radiofrequency treatment and germination and field emergence were accelerated. Genetic observations on grain sorghum revealed no increase in the number of mutants due to treatment. In Washington, information was obtained on the effect of glow-discharge treatment on the emergence of winter wheat. Effects on

coleoptile length were studied, since prior research has established that seedling emergence and vigor are directly related to the length of the coleoptile. Greenhouse tests showed no increase in coleoptile length due to irradiation; however, some decrease in plant height with no decrease in coleoptile length was observed. Since breeders are interested in developing varieties with shorter straw, field trials to study emergence, plant height and yield are underway.

Solar Grain Drying and Conditioning. In Kansas, a plastic solar collector to heat outdoor air was compared with natural air alone for fall high-moisture grain drying "in storage." Research in 1960 was expanded from experimental scale bins to 1000-bushel milo storages. Similar results to those obtained in previous year small-scale tests were obtained. A 45 percent reduction in the blower energy when using solar heat supplementation, as compared to natural air drying, was found in 1960. The following year, solar supplemented drying was compared with conventional natural air for sorghum grain drying for higher moisture contents (25 percent) than previously investigated. The solar supplementation provided successful drying without other supplemental heating equipment. Concurrent drying with natural air required fuel-fired supplemental heat to avoid grain spoilage. Blower energy required with solar supplementation was approximately 60 percent of that in which natural air alone was used and averaged 0.1 kw.-hr. per bushel per percent moisture removed to safe storage level of the grain. A partially air-supported ground surface solar absorber (fabricated from plastic film) was used for solar heat collection. Additional designs of heat-sealed air-inflated or supported film collectors have been fabricated for testing for possible easy portability, facility in use, and compact storage.

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SOIL AND WATER MANAGEMENT AND CONSERVATION
FOR GRAIN CROPS

Soil and Water Conservation Research Division, ARS

Problem. The importance of soil and water conservation in the nation's agriculture can hardly be overestimated. Without these natural resources there would be no agriculture - no crops - no food - no fibers--the nation's very existence is dependent on its soil and water resources. The development of improved tillage, crop residue management, fertilization, drainage and irrigation practices requires not only a knowledge of soil and climatic factors, but also widely varying moisture, temperature and nutrient requirements for establishment and growth of different crops.

Each crop and each physiographic area presents specific problems on soil and water management and conservation. For some crops the problem is excessive moisture at seeding. For other crops, adequate moisture must be provided at seeding. High soil temperatures are critical for some crops, whereas low soil temperatures are the major problem for other crops. For legumes, proper inoculation may be a problem. Consumptive use of water, water use efficiency and proper timing of moisture and fertilizer applications need further study for various crops. In studying these various factors, different crops are used as tools to measure soil and water research responses.

USDA PROGRAM

The Soil and Water Conservation Research Division has a continuing program doing basic and applied research and employing 17 disciplines to increase knowledge in all phases of soil and water management and watershed engineering. The total professional man-years involves 416 trained and specialized workers. These man-years have not been broken down by commodities.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Stations in 1961 reported a total of 4.0 professional man-years for grains.

REPORT OF PROGRESS FOR USDA AND COOPERATING PROGRAMS

At Ithaca, New York, the physical relationships that govern the intensity and quality of radiation distribution within the crop canopy have been well established. Within the action spectrum for photosynthesis (solar radiation between 0.3 and 0.7) it has been found that Beer's Law is applicable. This is also true of the near infrared portion of the solar spectrum (0.7 to 3.0). From this relationship, it is suggested that in further work on photosynthesis efficiency the crop community be characterized by an absorption coefficient as a function of depth of plant cover to replace "leaf area index."

Studies of photosynthesis and transpiration rates in a corn field under bright sunlight at Ithaca, New York, indicate that increasing wind increases photosynthesis rate, but does not affect transpiration rate. Evidently, photosynthesis is governed by the supply of carbon dioxide brought to the leaves by the wind movement. On the other hand,

transpiration is governed by the energy available, and is not influenced by the rate at which the water vapor can be removed from the leaves. This means an increased efficiency of water use with increasing wind, or in other words, a higher production of dry matter per unit of water lost by transpiration.

A convenient field instrument using thermistors to measure leaf temperatures was developed in Illinois. Initial studies indicate that corn leaves in sunlight were 0.5° C. cooler than the ambient air, while lower green leaves, in the shade, were as much as 6.5° C. warmer than the air. The work appears to indicate that transpiration has a cooling effect on plant leaves and thus may be necessary for plant survival.

In studies of plant-water relations conducted at Ithaca, New York, it was found that the relative turgor of the plant follows a diurnal cycle, the amplitude of which is governed by soil moisture and evaporative conditions. The sequence of conditions involved in drouth status of a plant is: First, there is a loss of turgor; second, loss in turgor somehow hampers the photosynthesis process; and finally, transpiration is decreased.

At Manhattan, Kansas, measurements of net radiation on sorghum plots having two row widths (20 and 40 inches) and two plant populations (60 and 480 sq. in. per plant) showed that for each row width when the plant population was high (60 sq. in. per plant) the crop plants themselves absorbed $93 \text{ cal./cm}^2/\text{day}$ more energy than when the plant population was low (480 sq. in. per plant). On the other hand, the difference in energy absorbed by the plant under high versus low plant population, was compensated by the amount of energy absorbed by the soil.

At Bushland, Texas, net radiation measurements made over an isolated irrigated grain sorghum field showed that during years of normal weather, the energy equivalent of the evapotranspiration ranged from 109 to 120 percent of the net radiation. As compared to a noncropped field, evaporation from black and white atmometers averaged 7 and 11 percent less, 600 and 50 feet, respectively, inside the upwind edge of the field. Both these observations support the conclusion that considerable energy for evapotranspiration was supplied to the field by advection.

In studies of materials for controlling wind erosion while vegetation was becoming established at Manhattan, Kansas, properly anchored vegetable mulches far exceeded, from the standpoint of cost and effectiveness, new materials that are claimed to be effective in controlling wind and water erosion. At quantities sufficient to control erosion, the total cost was \$89 to \$150 for hauled-in and anchored wheat straw mulch, \$247 per acre for cutback asphalt, \$335 per acre for asphalt-in-water emulsion, and about \$1,000 per acre for latex-in-water emulsion. Wood cellulose fiber was effective in controlling wind erosion at a cost of \$95 per acre, but was ineffective in controlling water erosion.

Resin-in-water emulsion was effective in controlling wind erosion of sandy soil at a cost of \$213 per acre, but was ineffective in controlling wind or water erosion on fine-textured soil. The vegetative mulch was the only material capable of appreciably reducing runoff. Of the five types of packers tested for anchoring vegetative mulches, the rolling disk packer was by far the most effective.

Contouring provided adequate erosion control for continuous corn grown on long, gentle slopes (420 ft.) of slowly permeable Mexico soil in Missouri during 6 of the past 8 years. However, extremely high soil losses in 1957 and 1961 brought the 8-year average annual loss to 4.3 tons per acre, or about 50 percent greater than the accepted maximum for this soil. The loss in 1961 was nearly 19 tons per acre. These data indicate that local rainfall pattern and soil permeability as well as steepness of slope must be considered when determining maximum field lengths for contoured row crops.

In a contour farming study at Marcellus, New York, begun in 1942, yield benefits of the practice increased significantly during the first two-thirds of the period. Since that time the established level of increase has been maintained on the average, although benefits have fluctuated widely from year to year. Contour benefits for beans during the later period varied the least, ranging from 13 to 30 percent with a mean of 20 percent. With wheat, the range was from 1 to 70 percent with a mean of 25 percent. Corn was the only crop not showing a contour benefit each year. Yield changes ranged from -8 to +36 percent with an average of 10 percent.

Grain sorghum, and dwarf field corn demonstrated optimum yields at water table depths of 24 to 30 inches. Protein and fat contents of grain from sorghum and corn were not affected by depth to water table. Oxygen diffusion in the primary root zone of the crop was quite good where the water table was maintained 18 or more inches beneath the soil surface.

At Weslaco, Texas, in an area where the water table declined from 40 inches at seeding time to 72 inches at plant maturity, soil moisture measurements taken at various growth stages of grain sorghum indicated that a substantial portion of the moisture used by the crop came from the water table.

Corn yields in a corn-Coastal Bermudagrass rotation at Florence, South Carolina, were no higher than those on continuous corn. In the Georgia Piedmont, rotations with legume sod crops increased corn yields by 10 to 20 bushels per acre as compared to the continuously cropped plots, even when 80 pounds of nitrogen was applied.

Rotation experiments in the Southern Plains have shown that two years of alfalfa or sweetclover increased dryland corn yields at Temple, Texas. At Bushland, Texas, the fourth irrigated grain sorghum crop

following two years of alfalfa averaged 500 pounds per acre more than continuous sorghum. At Cherokee, Oklahoma, alfalfa in an alfalfa-wheat rotation supplied sufficient nitrogen for maximum yields of wheat for two years following alfalfa, but nitrogen deficiency developed in third-year wheat.

In western Minnesota, eastern North Dakota, and eastern South Dakota, a combination of management practices that should give the most efficient use of soil moisture are being studied. About one-half of the locations showed a response to variations in corn population, one-third to nitrogen additions, and one-fourth to phosphorus additions. In 1960, good correlations between corn yields and the amount of moisture stored in the soil at planting time were obtained. However, in 1961, rainfall during the growing season was a better indicator of crop yields.

Because stored soil moisture must be relied upon to produce a normal corn crop at Morris, Minnesota, considerable effort has gone into the development of management practices that will increase the amount of water stored from precipitation during the fall and winter. Measurements made in 1961 showed that 22, 43, or 52 percent of the precipitation was stored during the fall and winter if the soil had been fall-plowed, if alfalfa was left standing, or if the soil cover was cornstalks, respectively.

Continued emphasis was placed on landforming and other mechanical means of conserving moisture at Mandan, North Dakota. On a bench terrace experiment, little runoff from the contributing area into the bench terrace took place during the drouth year of 1961. Wheat yields averaged 17.0, 13.3, 7.2, and 3.2 bushels per acre for fallow with no contributing area, continuous wheat with a waterproofed contributing area, continuous wheat with a grass contributing area, and continuous wheat, respectively. Fallow treatments had an unusually good moisture supply at seeding time owing to an optimum previous season. On a field-scale study at Mandan, corn yields averaged 14.1, 8.9, and 2.1 bushels per acre on level benches with contributing areas, level benches without the contributing area, and on the contributing area, respectively.

Land forming in the Red River Valley is more a water spreading practice than a surface drainage practice. Soil moisture is more uniform on land formed plots with consequent better operation of field machinery. Seeding is possible earlier in the spring and tillage is possible sooner after rains. While corn and barley yields on well drained parts of the field may not be increased, land forming increases average yields by both increasing yields on former depressed wet areas in the field and permitting more timely farming of the remaining areas in the field.

Residue management to retain large quantities of prior-crop residues at or near the surface very effectively reduced runoff and erosion from both corn and small grain in tests in five Corn Belt states. During the past 8 years, corn following corn with chopped corn stover mulch and added barnyard manure averaged 80 percent less runoff and 93 percent less soil loss than a corn-oats-meadow rotation without the mulch and manure on Fayette silt loam with 16-percent slope. Comparable results were obtained from a 7-year similar study on Dodge silt loam with 8-percent slope. In an 8-year test on the Midwest claypans, erosion from continuous corn at very high fertility was further reduced about one-third by leaving a mulch of shredded corn stalks on or near the surface. Using a field cultivator instead of a moldboard plow to prepare the seedbed reduced erosion from first-year corn after meadow from 5.9 tons per acre to 1.8 tons at La Crosse, Wisconsin, and reduced soil loss from oats from 12 tons to 5 tons.

At Cherokee, Oklahoma, runoff from small rings placed in field plots was correlated with the plot runoff. The relation was curvilinear and much closer for major runoff-producing storms in which the entire plot area contributed to runoff. Infiltration rates were similar on lovegrass and alfalfa plots. Initial rates were high on wheat plots because of loose surface soil from seedbed preparation. Soil concentration in runoff water was increased 6 times by removing wheat stubble surface residue and 12 times by removing lovegrass top growth with very little influence on infiltration.

On the basis of 1960 and 1961 results at Pendleton, Oregon, vertical mulching is not a recommended practice in the Columbia Basin of Oregon. The mulched trenches reduced runoff and erosion only when they were open to the surface. Tillage and seeding operations after vertical mulching tended to seal the surface with loose soil and essentially eliminated any beneficial effect of the trenching. At harvest time, strips 12 to 20 inches wide over the trenches were bare of wheat. Work near Rockford, Washington, showed that vertical mulching had no appreciable effect on the growth of alfalfa.

Studies on the stratified, high-silt Malheur soils in southeastern Oregon indicate that deep plowing may be useful on these soils. Crop yields were greatly increased the first year after plowing. Water infiltration and water and root penetration were greatly increased. Preliminary data on the change in the salinity and exchangeable sodium content indicate that the salts and exchangeable sodium were markedly reduced within 2 crop years.

Runoff and soil loss data at Watkinsville, Georgia, show there is little hazard from erosion on moderately sloping land, even under very severe rainfall conditions when row crops follow sod crops on contour-farmed land. Rainfall in 1961, totaling over 62 inches was 33 percent above normal and the rainfall erosion index was 200 percent of the

22-year average. Soil loss from a 3-year rotation of fescue, fescue and corn; a 4-year rotation of fescue, fescue, corn and cotton; and continuous cotton was in the ratio 1 to 7 to 47, respectively, and runoff was in the ratio 1 to 3 to 8. These findings strongly indicate that sod-based rotations are essential for production of row crops on sloping Piedmont land if conservation of rainfall and soil are to be attained practically.

Minimum tillage for corn has proved effective in studies in New York and New Jersey and on medium- and coarse-textured soils in Virginia. On clay soils in western Virginia, however, poor stands continue to be a problem. Corn following sod with no tillage, using either herbicides or black plastic to kill the sod, gave yields as high as conventionally tilled plots in Virginia and New York. Soil moisture was higher under the nontilled than under conventionally tilled plots.

In the Corn Belt, minimum tillage for corn has effectively increased infiltration and decreased erosion. From studies using a field plot rainfall simulator in Indiana, soil losses from the third successive year of corn were essentially double those from the first-year corn for both conventional and minimum tillage. However, the relative effectiveness of the minimum-tillage was only very slightly less in the third year of corn than in the first year after sod.

Tests in both Indiana and Wisconsin showed that the potential benefits of minimum-tillage practices may be lost as a result of soil crusting by intense rainfall early in the growing season. When surface crusting was eliminated by cultivation, minimum-tillage reduced soil loss about 40 percent, even when corn was mature. Four or five months after planting, the minimum-tilled plots were still much less compacted than the conventionally treated check plots. During the critical first two months after corn planting, Wisconsin studies showed minimum tillage methods were most effective when plowing and planting were on the contour. Wheeltrack planting on the contour on Fayette silt loam with 16-percent slope lost 0.33 inch in runoff and 0.8 ton soil per acre from natural rainfall, compared with 0.86 inch in runoff and 5.8 tons of soil from adjacent "conventionally" planted corn, also on the contour.

A surface mulch of chopped hay superimposed upon the plow-plant method greatly reduced runoff and almost eliminated soil loss from Russell silt loam, a well-drained soil in Indiana, during two test periods in each of which 5 inches of simulated rain was applied at 2-1/2 inches per hour. About one-half ton of soil was lost from this treatment as compared with 13 tons from a similar minimum-tillage treatment with no mulch. Orchardgrass and alfalfa hay harvested from adjoining strips equal in area to the corn plots were chopped and blown over the corn plots after first cultivation. These preliminary results indicate that this treatment may be very effective in controlling

erosion on short irregular slopes where contour-type conservation practices are not feasible. The plow-plant method would control erosion during the early weeks after planting, the single cultivation would destroy crusts produced by early rainfall, and the mulch would prevent sealing and ready transport of soil by subsequent rainfall without the adverse effects of mulch on soil temperatures in the early spring.

At Sidney, Montana, chemical fallow has not been as successful as tilled fallow in conserving moisture. This was due largely to incomplete control of wild oats by the chemical. At the Pendleton and Sherman stations in the Columbia Basin of Oregon, chemical fallow (1.6 pounds atrazine plus 1.0 pound amitrole per acre) did not have a significant effect on moisture conservation, nitrate production, or on the population of soil micro-organisms. There was, however, a decrease in grain yield due to the chemical treatment at the Pendleton location (23.1 compared to 29.7 bushels per acre). This depression in yield was not noted at the Sherman location nor at Pendleton on the chemical treatments that were tilled.

Summer fallow tillage experiments for moisture conservation in the dryland winter wheat area of eastern Idaho show that delaying plowing reduces moisture storage at seeding time. When plowing was done early with the soil at field capacity, the available moisture at seeding time was 13.9 percent as compared with 9 percent for the treatment that was tilled when the top 6 inches had lost all available moisture. The treatment tilled when the top 6 inches had lost one-half available moisture had 10.7 percent moisture at planting time.

In comparing annual cropping with summer fallow for spring wheat at St. Anthony, Idaho, it was found that fall chiseling permitted storage of 72 percent of the winter precipitation as compared to 41 percent on the treatments not chiseled. Eighty-six percent of the deviation in yield was accounted for by the amount of stored moisture at the start of the growing season, with each inch of stored moisture producing 2.12 bushels of wheat.

Wheat yields in Nebraska and Colorado and corn and oat yields in Nebraska have been less on stubble-mulched plots than on conventionally tilled treatments. Laboratory studies at Lincoln, Nebraska, show micro-organisms may produce phytotoxic substances which, in some cases, could account for yield reductions of wheat and corn.

Experimental results obtained at Ames, Iowa, demonstrate that crop residue mulches may decrease the availability of manganese needed for early growth of corn. Mulched corn plants sampled 25, 34, and 41 days after planting contained 81, 32 and 34 ppm of manganese, respectively, as compared to clean-cultivated plants with 145, 69, and 40 ppm.

In Mississippi, corn yields did not differ significantly when planted in mulch, tractor tracks, or a well-prepared seedbed. Six tons of corn residue left on the surface over winter and partially incorporated at planting time reduced growth, nitrogen uptake and yield of succeeding corn crop by about 25 percent. Plowing under the residues partially eliminated these reductions. The carryover of fall-applied nitrogen was the same for all residue management systems.

At Bushland, Texas, wheat on fallow appeared to be able to extract moisture from the fifth and sixth feet of soil more effectively than did continuous wheat. This may have been due to more extensive rooting systems in the fallowed wheat.

Corn yields on Moody silt loam in Iowa have been higher on conservation tillage practices than on conventional practices under conditions of low soil moisture at planting and/or midsummer drouth. Under favorable moisture conditions, yields were not greatly different among the tillage methods tested.

At Cherokee and Woodward, Oklahoma, clean-tilled land outyielded stubble-mulched land when no fertilizer was applied, but wheat yields on stubble-mulched land were equivalent or greater than on clean tilled when 40 pounds of N was applied.

At Riverside, California, in a dryland alternate fallow-grain system, both a knowledge of available soil moisture and nitrogen (or potentially available) at planting time are required in predicting what the effect of applied nitrogen will be. On a rangeland study in a season with one-third average annual rainfall, the soil moisture was more efficiently used when 60 pounds of nitrogen and 14 pounds of phosphorus per acre were applied.

Studies conducted at Fort Collins, Colorado, show that the effect of soil texture on available P and the amount of fertilizer P needed to produce equal rates of P uptake could be explained more adequately by applying the concept of diffusion of P. Differences in rates of uptake predicted from diffusion equations were observed in actual measurements of rates of P uptake by plants. As a result of this approach, a sound basis is provided to develop a method for determining the amounts of fertilizer phosphorus needed to give equal levels of available phosphorus on soils varying in texture. A clay soil requires two to three times as much fertilizer phosphorus as a fine sandy loam (calcareous or alkaline soils) to produce the same plant response when both soils are initially very low in available phosphorus. An exact quantitative evaluation of this textural effect has not been possible because of variations in maximum yields among soils.

Short-term phosphorus uptake studies were conducted at Fort Collins, Colorado, with intact month-old corn plants of differential nitrogen and phosphorus composition. Supplemental nitrogen pretreatments producing increased growth rates and higher levels of nitrogen in the plant, stimulated the rate of phosphorus uptake per gram dry weight of root more than tenfold. The presence of nitrate or ammonium ions in the test solution during the uptake period had negligible effects on phosphorus uptake rates. The increases in phosphorus uptake rates may be general effects of the increasing demand for phosphorus within the plant with increased growth rates, but the magnitude of these effects suggests a more direct connection. Phosphorus uptake rates were highly correlated with total nitrogen level in the root.

Results of study on the influences that stage of barley growth and soil moisture tension have on the absorption of P conducted at Bozeman, Montana, showed that most of the P was absorbed by barley in the tillering to heading stage. No P was absorbed from a soil near the wilting point. However, uptake started eight hours after the soil was brought to field capacity on a fine sandy loam soil and after 32 hours on a silty clay loam. A high moisture zone did not aid the plant in removing P from an adjacent low moisture zone.

Studies to determine the best combination of corn population, fertilizer, and other management practices for efficient moisture use in western Minnesota, eastern South Dakota, and eastern North Dakota showed that corn population, nitrogen additions and phosphorus additions increased the water use efficiency values.

At Akron, Colorado, moisture studies with grain sorghum have shown that approximately 9 inches of water (growing season rainfall plus moisture stored in the soil at planting time) are necessary for a bushel of grain to be produced. Average growing season rainfall (June-August) is 7.2 inches. Soil moisture utilization in the profile was increased 1 inch by the addition of 60 pounds of N. Maximum moisture use occurred during the time the plant was making rapid elongation.

Results of greenhouse experiments conducted at Beltsville to study soil N uptake at various fertilizer N levels have shown that the uptake of soil nitrogen by oats increased with increasing rates of fertilizer nitrogen. The maximum effect of N application on the uptake of soil N for the 12 soils studied averaged about 30 percent above the control. The percentage uptake of fertilizer nitrogen also increased with rate of application. Present evidence indicates that such differences in nitrogen uptake can be best explained by the differential immobilization of mineral nitrogen by rhizosphere micro-organisms in the utilization of energy material derived from roots of varying carbon-nitrogen ratios.

In an experiment to study the effects of nonuniform fertilizer distribution on corn yields in South Carolina, results showed that fertilizer distribution could vary as much as 40 percent from uniformity without causing a significant yield decrease. In this study all whole plots received the same amount of fertilizer but the distribution pattern in rows varied.

Studies on the availability of residual nitrogen from applied ammonium nitrate fertilizer to summer fallow wheat were continued at Pendleton, Oregon. Where more than 80 lb/A. N were applied for the 1959 crop, sufficient residual N was available to increase yields of the next (1961) wheat crop. It now appears that successive applications of about 40 to 50 lb/A. N on each wheat crop is adequate to maintain maximum yields in the 15- to 16-inch rainfall area. In the 11- to 12-inch rainfall area, about 30 lb/A. N appears to be adequate.

In another experiment, urea and ammonium nitrate, respectively, were used as the sole nitrogen carrier in 1:1:1 liquid fertilizers applied in different amounts up to 150 pounds per acre, and according to different time schedules, to corn growing on Davidson silty loam soil in greenhouse culture. The stover yield and phosphorus uptake increased with the amount of fertilizer applied in all treatments and were significantly greater with ammonium nitrate than with urea.

Current trends for the higher use rates of fertilizer in crop production have imposed new parameters on the concept of nutrient balance and absorption in relation to yield. At Beltsville, Maryland, the interrelations between cation and anion uptake and content of plants have been reexamined. Under conditions where high amounts of fertilizers are used, research results show that the main function of cations is to supply positive charges which enables the plant to maintain the pH and the organic acid content within a narrow range, and that this is a prerequisite for good growth. This information will allow a more rationalized method for composing fertilizer mixtures to be developed.

A direct physical picture of the pathway of ion uptake in the plant roots is needed to clarify the role of the soil as a source of nutrients in relation to the ion uptake process by the plant root. Techniques have been developed for preparing high resolution autoradiographs. This is the first step in determining the initial sites of ion entry and accumulation.

Hexadecanol, a straight-chain alcohol, is known to form a film on a water surface, such as a pond, and to reduce evaporation. It has been suggested that hexadecanol might form a similar film on the evaporating water surfaces within a plant or soil, and thus decrease evapotranspiration. Corn was grown in the greenhouse in Illinois in containers which were sealed to prevent evaporation from the soil.

In two experiments hexadecanol caused the plants to use less water, but only by causing the plants to grow less. The amount of water used per square centimeter of leaf was unchanged. In other greenhouse experiments hexadecanol additions did not reduce evaporation losses from clay or loam soils but did cause a significant decrease loss from sand. Much of the water movement above the water table in coarse sand is by vapor transfer, whereas most of the water movement in finer materials is by capillarity. Hexadecanol might be expected to interfere with vaporization within the soil more than with capillary movement.

Two comprehensive field experiments were conducted in Illinois in 1961 in which water use by corn was measured as influenced by broadcasting and banding additions of octa-hexadecanol to the soil. In one experiment the soil surface was completely plastic-covered and hence transpiration and drainage were the mechanisms of water loss. In the other experiment the soil was not covered and thus evaporation was an added component of water loss. No statistically significant difference in either water use or corn yield occurred as a result of octa-hexadecanol application. There was, however, a slight, but statistically significant, reduction in plant height associated with the octa-hexadecanol treatments. It was also found, in a laboratory experiment, that a synthetic resin did appreciably reduce soil evaporation; however, the application made the soil surface resistant to wetting.

The effect of octadecanol on the evapotranspiration rate of corn was studied in the greenhouse at Tempe, Arizona. Three rates (670, 3,350, and 16,750 pounds per acre) and two placement methods (thoroughly mixed and banded 8 cm below the surface) were used. During the first 18 days after seeding there was no significant effect upon evapotranspiration by the above chemicals. During the eight weeks of growth, two cycles of evapotranspiration showed no effect of octadecanol on lowering water loss as compared to control values. An early tendency to stunting at the 25-g dosage rate did not result in any significant difference in final dry weight between treated and control plants.

Corn grown on plots covered with white plastic at Fort Collins, Colorado, yielded 16 percent more than corn grown on plots with no cover and 5 percent more than corn grown on plots with a black cover. Water was not a limiting factor in this experiment. Sensible heat from the soil surface to the air, calculated from air temperature gradients, was increased 130 percent by covering the soil with black waterproofing and decreased 44 percent by covering the soil with white waterproofing. These data indicate that energy not used to evaporate water in the soil can be reflected if the water-proofing material is light in color. In an evaporation study using lysimeters at La Crosse, Wisconsin, water use by corn on covered plots was 49 percent of that for the corn grown on the uncovered lysimeter.

A transparent plastic mulch used at Marcellus, New York, increased soil temperatures and early plant growth. Corn yields on the control plot were 109 bushels as compared to plastic mulch yields of 124 bushels for the normal season hybrid and 134 bushels for the late hybrid. On plots with a sealed plastic cover, 113 bushels of corn per acre were produced with the estimated 6-8 inches of available water at planting time. At no time during the season was there evidence of moisture stress.

II. UTILIZATION RESEARCH AND DEVELOPMENT

CEREAL STARCHES - INDUSTRIAL UTILIZATION

Northern Utilization Research and Development Division, ARS

Problem. Starch accounts for about two-thirds the weight of all grains. Finding new, large-volume outlets for starch would, therefore, result in substantially increased consumption of cereal grains. Of the 4.5 billion pounds of cereal starch now produced, about 2.7 billion pounds is used ultimately in food products, and increases would be expected to follow population growth. However, the remaining 1.8 billion pounds find industrial outlets that offer opportunities for increases at a rate greater than that of population growth. Because starch must compete with products derived from nonagricultural sources, these opportunities can best be realized by a program of research designed both to maintain the competitive position of starch in its current uses and to develop economical new industrial uses.

New outlets for cereal starches and flours equivalent to over 200 million bushels of grain by 1975 can be envisioned if basic research and development on several types of chemical and physical modification of starch and flour now in the experimental stage or anticipated can be prosecuted to successful conclusion. About 150 million bushels could be required for new products for the pulp and paper industries and for the building and construction industries, and about 10 million bushels each for other industries such as the chemical, petroleum, mining, textile, plastics, coatings, and packaging industries. New outlets for starch that appear very promising include use of modified starches as wet-strength additives for paper, water-resistant adhesives, coatings, and foamed products, and of starch-derived pulps as an integral part of high-quality paper. In addition, if the competitive position of starch is successfully maintained through improvement by research, additional consumption would be expected by 1975 from participation in markets for 100 million bushels of grain resulting from normal growth of existing industrial outlets for starch and flour such as paper, textiles, packaging adhesives, drilling muds, and building materials.

To accelerate realization of these goals, more information is needed on the physical and chemical properties and chemical reactions of cereal starches, on economical methods for effecting desired physical and chemical modifications and on product evaluation and development. In addition, still further new markets for cereal starches should be possible from an adequate program of fundamental and exploratory research to discover new concepts, principles, and reactions leading to new processes and products for future development.

USDA PROGRAM

The Department conducts a continuing, long-range program of research involving analytical, organic and physical chemists and chemical engineers engaged in basic, applied and developmental studies on the chemistry of cereal starches and their conversion to useful industrial products.

The Federal scientific effort for research on cereal starches totals 30.8 professional man-years. Of this number 7.9 are devoted to chemical composition and physical properties and 22.9 to new starch chemical derivatives and their evaluation.

Research at Peoria, Illinois, on chemical composition and physical properties (6.1 professional man-years) involves fundamental research on reactions of starch and dextrose in nonaqueous solvents. Research contracts under this subheading (1.8 professional man-years) are in effect with the University of Arizona, Tucson, Arizona, for basic studies on the reaction of starch with mercaptans (.6 professional man-year) and with acetylene (.5 professional man-year); and with John Hopkins University, Baltimore, Maryland, for basic research on the reactions of starch in fluid dynamic media (.7 professional man-year).

Research at Peoria, Illinois, on new starch chemical derivatives and their evaluation (21.0 professional man-years) involves basic and applied studies on various types of chemical products derived from starch, dextrin and dialdehyde starch and in evaluation of these products for various industrial uses such as plastics, coatings, pulp and paper products, organic chemicals and stable viscosity agents. During the reporting period research was discontinued on methods for producing dialdehyde starch and on evaluation of dialdehyde starch as a wet-strength additive for paper and as a component of paper coatings. Research contracts under this subheading (1.9 professional man-years) are in effect with the University of Minnesota, St. Paul, Minnesota, for studies on reactions of dialdehyde starch in solution (.4 professional man-year); with Ohio State University, Columbus, Ohio, for research on synthesis of amino derivatives of starch (1.2 professional man-years); and with the State University of New York, Syracuse, New York, for evaluation of crosslinked hypochlorite-oxidized starches in papermaking (.3 professional man-year). During the reporting period contract research on the following lines of work was completed: development of an electrolytic cell for production of dialdehyde starch; methods for using dialdehyde starch in leather tanning.

The Department also sponsors research on cereal starches (29.5 professional man-years) conducted by foreign institutions under grants of PL 480 funds. Research on chemical composition and physical properties (15.0 professional man-years) involves grants to the Institute of Fibres and Forest Products, Jerusalem, Israel, for research on

hypohalite oxidation of cereal starches (3.0 professional man-years); University of Birmingham, England, for research on starch structure as revealed by interaction of starch and enzymes (4.0 professional man-years); National Institute of Hygiene, Paris, France, for research on proteolysis inhibiting effects of cereal starches and flours (3.5 professional man-years); National Institute of Agronomic Research, Paris, France, for research on changes induced in starch by gamma irradiation (2.5 professional man-years); and Scientific Institute for Chemistry and Biochemistry, Milan, Italy, for research on glucopyranose rings in starches and dextrans (3.0 professional man-years). New starch chemical derivatives and their evaluation (14.5 professional man-years) involves grants to the Arthur D. Little Research Institute, Inveresk, Scotland, for research on glucose-derived polymers (4.0 professional man-years); Hebrew University, Jerusalem, Israel, for studies of methods for preparing fluorine derivatives of starch (2.3 professional man-years); Institute of Industrial Chemistry, Bologna, Italy, for studies on fatty chemical derivatives of starch dextrans (3.2 professional man-years); and National Institute of Technology, Rio de Janeiro, Brazil, for research on phosphorus- and sulfur-containing cationic starches (5.0 professional man-years).

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Stations in 1961 reported a total of 14.2 professional man-years divided among subheadings as follows: chemical composition and physical properties, 5.4 professional man-years; industrial chemical products, 1.6 professional man-years; and processing technology, .3 professional man-year.

One phase of starch research involves establishing the mechanism of attack of oxidants such as chlorine, chlorine dioxide and hypochlorite on starch at different hydrogen ion concentrations. This work contributes to the regional study of soft wheat starches, NCM-28, Marketing, Quality and Utilization of Soft Winter Wheats. Other objectives of the regional effort include soft wheat starches, air classification and utilization of starch fractions in commercial products. The USDA Soft Wheat Laboratory participates in this regional project. Several approaches to the chemical and enzymatic modification of starch are grouped under a well-coordinated regional project plan, NCT-56, Modification of Starch for Industrial Uses.

Enzyme characterization of starch structure is also under study. Starch gelatinization, structure and reactivity of starch granules, and fundamental properties of colloid systems are also being investigated.

Use of corn products coatings for control of shrink and preservation of quality in foods is under study. Another aspect of work involves

an exploratory investigation of the production of hydrophilic polymers from carbohydrates.

Processing technology research involves development of ways to extract and characterize the various components of corn.

Industry and other organizations including the state governments also conduct research to develop new or improved industrial and food products from refined cereal starches. Such research is conducted primarily by companies engaged in wet milling of corn.

The principal research activity of most of these companies is applied and developmental research on products for industrial use. Next in importance is processing research, followed by research on new food products. Basic research is conducted by nearly all companies, several of which individually support relatively large programs. Through the Corn Industries Research Foundation, the companies support an important additional amount of basic research on corn starch. Consuming industries, such as the paper, textile, adhesive, mining and petroleum industries, maintain a very substantial research program designed to improve their own products that contain existing, commercially available starches and modified starches. Since this research is not believed to be concerned with discovery and development of new or improved products by chemical or physical modification of starch, the magnitude of this research effort is not included in the estimates given below.

Corn wet-milling companies frequently cooperate in evaluation of products and processes developed by the Department. Except for such cooperative work, the exact nature of the products and processes investigated is kept confidential by the companies or patented. Estimated annual expenditures for research on cereal starches by the companies are equivalent to approximately 90 professional man-years in basic research, 70 professional man-years in applied and developmental research on food products, 17⁴ professional man-years in applied and developmental research on industrial products, and 90 professional man-years in research on processing.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties

1. Reactions of starch and dextrin in nonaqueous solvents. The structure of isomaltol was proved to be 2-acetyl-3-hydroxyfuran. Maltol was obtained by treatment of maltose hydrate from starch with morpholine phosphate in dimethyl formamide. Isomaltol also was formed, but in lower amounts and well below the yields previously obtained from lactose. The objective of this research is to develop procedures for

making these flavoring agents from starch. They are now obtained as a byproduct of the wood distillation industry.

Imino-bis-1-deoxy-D-glucitol (disorbityl amine), which has good metal chelating properties, was prepared by hydrogenation of di-D-glucosylamine. Disorbitylamine hydrochloride has been produced in 59-percent yield (crude) by hydrogenation of the reaction product of dextrose and ammonium chloride in dry liquid ammonia. Disorbitylamine sequestered much more copper and iron than diglucosylamine or N-methylglucamine (e.g., 1.3 vs. 0.1 atom Fe^{+++} /mole at pH 7). In strongly alkaline solutions it sequesters slightly less calcium and slightly more strontium than sodium gluconate or glucoheptonate.

The good metal chelating properties of disorbitylamine, when compared to the commercial products sodium gluconate and glucoheptonate, suggest that this product merits further consideration for industrial use. Possibilities are further enhanced by opportunities for chemical modification of this amine. For example, selective esterification with fatty acids should yield a molecule combining surface activity and sequestering ability. This type of product should have many uses in the fermentation and food industries; feeding tests for toxicity have yet to be done.

2. Starch acetylene reaction. Initial contract studies at the University of Arizona showed that acetylene reacts with starch; a degree of substitution in the range of 0.3 to nearly 1 was obtained in first experiments with no appreciable formation of undesired cyclic acetal. Thirty-two vinylations of starch by reaction with acetylene were carried out according to a fractional factorial design. Statistical analysis of the data is in progress to obtain information on reaction variables.

3. Hypohalite oxidation of starches. At the Institute for Fibres and Forest Products Research, Jerusalem, Israel, kinetic studies of the mild oxidation of wheat starch with alkaline hypochlorite have been completed. The reaction is first order with respect to starch at pH 8; activation energy 21-23 kcal/mole. Neutral salts accelerate the reaction rate. Absence of chlorate indicated that the reaction proceeds according to the equation: $\text{Starch} + \text{NaOCl} \longrightarrow \text{Starch-O} + \text{NaCl}$. The action of hypochlorite appears to be random and similar for both wheat and waxy corn starches. Parallel studies have shown that hypobromite reacts 50 times faster than hypochlorite. Procedures have been developed (1) for determining small concentrations of carbonyl groups in starch by means of the cyanohydrin reaction, and (2) for estimating the number-average degree of polymerization of amylose and amylopectin in degraded starch without recourse to fractionation. This work is providing needed basic information on a process used to produce oxidized starches commercially in the United States.

4. Starch structure. Analytical ultracentrifugation studies, in progress at the University of Birmingham, England, have shown that properties of starch when dispersed in alkaline solution are extremely responsive to changes in the conditions of dispersion. Exact control of these conditions is necessary if the components of starch are to be obtained in a relatively undamaged state. Studies of the changes that occur during the first few minutes of dispersion have resulted in development of a method for fractionating starch into amylose and amylopectin by differential sedimentation of neutralized alkaline dispersions of starch. This research is providing important new basic information on the chemical and physical properties of starch.

5. Proteolysis inhibition by starch. The National Institute of Hygiene, Paris, France, has reported that different types of starches reduce peptic proteolysis of milk to different extents. Adsorption of proteolytic products on starch may be an important contributing factor. These studies are designed to elucidate the alleged antitryptic activity of raw wheat flour.

B. New Starch Chemical Derivatives and Their Evaluation

1. Dialdehyde starch (DAS) production and evaluation. In the final work on process development, the annular cell was improved to permit a 300-percent increase in production per cell. Based on the annular cell, a multistage reactor system was developed in which both oxidation of starch and reoxidation of the oxidant are accomplished continuously with a reduction of operating manpower. Although the continuous process has not been perfected, its feasibility has been demonstrated.

In the use of DAS as a wet-strength additive for paper at the 0.5-percent level (based on dry weight of pulp) retention of DAS was about 60 percent in the presence of cationic starch as a retention aid. By recycling the white water, retention of 98 percent of the DAS was achieved. This procedure significantly improves the economics of using DAS as an additive in paper. In addition to its use for increasing wet strength of paper, DAS offers promise as a component of adhesives needed in papercoatings. Effects of pH and concentration on crosslinking of casein by DAS in aqueous borax dispersions were investigated. Varying ratios of DAS to casein gave insoluble products differing in composition. Maximum combining power was found to be 25 g. DAS per 100 g. of casein. Viscosity stability could be achieved by maintaining reaction mixtures under slightly acidic conditions. Rapid reaction and gelation occurred under alkaline conditions. Pigmented papercoatings were made from DAS-casein dispersions that had extremely high wet-rub resistance and were superior to many coatings now used commercially.

Contract research at the Armour Leather Company showed that it is possible to reuse DAS pretanning solutions after proper fortification. This finding is of basic importance to the development of an economically attractive process. Evaluation tests at the Eastern Utilization Research and Development Division showed that sole leather comparable to regular sole leather was produced by use of DAS and vegetable tanning. Ten replicate runs based on reuse of the DAS pretanning solution were completed. Although research under the contract has been terminated, the project is being kept active to cover service tests on the sole leather to be made by the Quartermaster Research and Engineering Command.

2. Chemical reactions of dialdehyde starch (DAS). Cationic DAS's have been prepared by periodic acid oxidation of commercial cationic starch or by reaction of DAS with di- and trimethylglycine hydrazides. Preliminary evaluation studies (not yet complete) show that these new products give excellent results as wet-end additives for increasing wet- and dry-strength of paper without use of a retention aid as presently required for best results with ordinary DAS. Even though cationic DAS's are more expensive than DAS, cost of using these new products in paper, especially those derived from DAS and di- and trimethylglycine hydrazides, is decreased because of elimination of the retention aid and because they are effective at low levels of application.

Depolymerization of DAS in methanol with sodium yielded a mixture of three polyfunctional aldehydes. Production in good yields by a simple reaction of these low-molecular-weight aldehydes is a promising route to materials that should have a variety of interesting industrial applications.

Use of 2,2-diallyloxypropane to speed up and drive the reaction between dialdehyde starch and allyl alcohol to completion by removing water of reaction gives a product, cured films of which are considerably more resistant to boiling water than are those obtained when 2,2-dimethoxypropane is used to remove water. The product obtained when 2,2-dimethoxypropane is employed contains methyl as well as allyl acetal groups and does not cure as fully as completely allylated dialdehyde starch. Films cured with a free radical catalyst at 80° C. were several times more resistant to alkali than those cured by the former method, i.e., at 150° C. without catalyst. Plans are being made to negotiate a research contract covering evaluation of allylated DAS films.

At the University of Minnesota, model carbohydrate compounds were prepared that yield after periodate oxidation simple low-molecular-weight analogs of DAS. These model compounds will assist in the study of chemical reactions of DAS and of changes that occur when DAS is aged or dispersed (as in paper and tannage applications).

The course of the degradation of aged, relatively insoluble dialdehyde starch by bisulfite was followed by means of the ultracentrifuge and appeared to proceed in three stages: (a) The formation of a small quantity of low-molecular-weight material, which is solubilized before swelling of the polymer is noted; (b) liberation of a fairly homogeneous major component of molecular weight of the order of 50,000; and (c) a further degradation of this component to a heterogeneous mixture of components. Studies further revealed that for intermediate levels of oxidation (29 and 43 percent) periodate acts randomly along the starch chain.

3. Allyl starches and dextrans. The major problem in utilizing allyl starch as a coating resin is development of a derivative that has desired solubility in organic solvents and that will yield films having satisfactory properties, especially in regard to curing, brittleness, and water resistance. A number of approaches have been tried unsuccessfully in an effort to achieve this goal. Some of these approaches are crosslinking of starch with epichlorohydrin before allylation; alteration of the starch chain by low level periodate oxidation; epoxidation with peracetic acid; allylation of dextrin; hypochlorite addition and dehydrohalogenation; and derivatization with unsaturated diepoxides. Study of allyl derivatives of amylose and high-amylose starch showed that the structural linearity of these products did not provide the desired improvement in properties. Polymerization of 60 to 70 percent of the allyl groups of an allyl dextrin was achieved with free radical initiation. Degradation associated with oxidative polymerization was thus avoided, but the product nevertheless had poor resistance to water and solvents.

These results, together with the excellent properties of allyl dialdehyde starch coatings, show that configurational differences in the position of the allyl groups play an important role. They have finally revealed the predominance of intramolecular polymerization as the probable reason for failure of allyl starches and dextrans to yield satisfactory films. It is now apparent that before preparation of satisfactory polymers from these materials can be achieved, methods for eliminating or controlling intramolecular polymerization must be developed. An extensive program of basic research on such subjects as selective substitution, extension or unfolding of the allyl starch or dextrin molecule, and use of blocking groups would be required before such methods can be devised.

4. Chemical products from starch and dextrin. Starch was reacted with dihydropyran, ethyl vinyl ether and fatty vinyl ethers to yield products that give dense stable foams, gels, waxlike products, and water-resistant films. Both water-soluble and organic-soluble products were obtained. Properties varied depending on the degree of substitution.

In initial studies, hydroxymethylfurfural (HMF) has been obtained from starch and glucose in substantially higher yields (over 40 percent) than has been reported in the literature. HMF can be used for making nylon. Yields of about 80 percent from starch could make the process economical. Starch and flour have been converted by a simple process involving inexpensive chemicals into liquid products that yield rigid foams by treatment with diisocyanates. The process has been successfully applied to corn, wheat, red milo, and other starches; wheat flour; and low-protein flour fractions.

In contract studies at Ohio State University, use of alkali metal derivatives of methyl α -D-glucopyranoside as intermediates for further synthetic reactions was found to be insufficiently selective for synthesis of amino sugars. Reduction of the reaction product of dialdehyde starch and phenylhydrazine gave a polymer believed to contain amino-substituted glucose units.

At the Arthur D. Little Research Institute, Inveresk, Scotland, two new types of carbohydrate-containing polymers have been synthesized. One series consists of nylon-type polymers prepared by interfacial polycondensation, and the other of polyvinyl addition polymers which carry pendant hexitol groupings attached by ester linkages. Reactants in the interfacial polycondensation technique are sugar diamines and dibasic acid chlorides, or diamines and sugar acid chlorides. Selected polymers are currently being evaluated by industrial firms in England.

In efforts to produce surfactants and define the limits of dextrin molecular weight relative to the degree of substitution and chain-length of fatty radicals for optimum surface activity, progress has been made in fractionating a commercial corn dextrin. However, the desired low degree of fatty substitution of the dextrin fractions has not been achieved. Esterification methods are being modified to lower the degree of substitution. This research is being conducted at the Institute of Industrial Chemistry, Bologna, Italy.

5. Crosslinked starch in paper. In contract work at the State University of New York, investigations were completed on the use of cross-linked, hypochlorite-oxidized starches for beater additives; no apparent advantages over commercial oxidized starch were found for bleached pulps. Data indicated that crosslinked, hypochlorite-oxidized starch merited further consideration as a retention aid and for use in surface coatings for paper, and that further studies should be conducted with unbleached pulps.

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WHEAT
INDUSTRIAL UTILIZATION

Northern Utilization Research and Development Division, ARS

Problem. Wheat traditionally commands a higher price than corn.

Since the starch content and starch properties of these two cereals are similar, new industrial uses for wheat must rely on advantages to be obtained from other components. Wheat flour is a mixture of starch, protein, gums, fiber, and fat. Because of the simultaneous presence of these basic ingredients, opportunities are promising for development of a wide variety of industrial products from wheat flour that would be expected to have properties and uses different from those of related products derived from refined starch. The problem is to find means for economical modification and reaction of these ingredients with each other and with other chemicals in order to realize the potential of the combinations.

Basic research now being conducted by the Department points to new potential industrial uses for cereal starches and flours that could consume over 200 million bushels of grain by 1975. Among potential outlets for wheat flour are sizes for many special grades of paper, cereal pulps that would form an integral part of such papers, and plastic or foamed compositions for hardboard and insulating boards. The opportunity for successful realization of these possibilities is enhanced by recently developed fine-grinding and air-classification milling techniques that permit the composition of flour to be varied over wide ranges. These techniques are now satisfactory for soft wheats, but ways must be found to adapt them to hard wheats which constitute 93 percent of the wheat remaining after current needs have been met.

Wheat flour could achieve its share of potential new markets more rapidly, and discovery of additional new uses under both public and private research programs would be facilitated, if more information were available on the basic physical properties and chemical reactions of flour and its components, on tempering and milling techniques, and on processing methods for economical conversion of flour to desired end products.

USDA PROGRAM

The Department conducts a continuing long-range program of research involving analytical, organic and physical chemists, chemical engineers and structural biologists engaged in basic studies of the chemical and physical properties of wheat, flour, flour fractions, and protein components and in applied research leading to new and improved wheat products for industrial use.

The Federal scientific effort for research on industrial utilization of wheat totals 45.2 professional man-years. Of this number 14.8 are devoted to chemical composition and physical properties; 18.7 to industrial chemical products; 6.8 to processing technology; and 4.9 to wheat structural products.

Research at Peoria, Illinois, on chemical composition and physical properties (12.4 professional man-years) includes separation, characterization and chemical reactions of the component proteins of wheat gluten. Research contracts (2.4 professional man-years) are in effect at Purdue University, Lafayette, Indiana, for fundamental studies of the alkaline desulfurization of gluten (.8 professional man-year); and Armour Research Foundation, Chicago, Illinois, for investigation of methods for controlled hydrolysis of gluten (1.6 professional man-years). During the reporting period contract research on isolation and characterization of sterols from wheat was completed.

Investigations on industrial chemical products conducted at Peoria, Illinois, (16.5 professional man-years) involve preparation and evaluation of new types of water-soluble and water-insoluble flour derivatives for industrial use. During the reporting period small-scale laboratory research on acid-modified flour was discontinued and pilot-plant studies on this product were initiated. Research contracts (2.2 professional man-years) are in effect with Stanford Research Institute, Menlo Park, California, for basic research on graft copolymers from wheat flour and starch (1.4 professional man-years); and Iowa State University, Ames, Iowa, for studies on development of improved adhesives from wheat gluten by reaction with dialdehyde starch (.8 professional man-year). During the reporting period contract research on evaluation of hydroxyethylated wheat flour in paper was completed.

Processing technology research at Peoria, Illinois, (6.2 professional man-years) involves studies on conditioning and milling of wheat and air classification of flours. A research contract (.6 professional man-year) with Kansas State University, Manhattan, Kansas, is concerned with study of the mechanism of enzyme formation during wheat malting and relationship of the information developed to control of enzymes and their action during milling and processing of wheat. During the reporting period contract research was completed on the effects of chemicals, such as gibberellin, on the enzyme activity of malted wheat.

Research at Peoria, Illinois, on wheat structural products (4.9 professional man-years) involves development of structural boards and foamed products from chemically modified wheat components. During the reporting period investigations on puffed-wheat particle board and on structural foams from chemically unmodified gluten and flour were completed.

The Department also sponsors research in this area (5.4 professional man-years) conducted by foreign institutions under grants of PL 480 funds. Research on chemical composition and physical properties (1.2 professional man-years) involves a grant to the Weizmann Institute of Science, Rehovot, Israel, for synthesis and study of polypeptides having amino acid compositions related to wheat gliadin. Research on processing technology (3.3 professional man-years) involves a grant to the Research Association of British Flour Millers, St. Albans, England, for investigations on quantitative measurement of properties of wheat that change significantly during conditioning.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Stations in 1961 reported a total of 5.3 professional man-years divided among subheadings as follows: chemical composition and physical properties, 3.1; processing technology, 1.8; and wheat structural products, .4.

Work is in progress on the biochemical properties of cereal grains which affect their processing and use. Another research program involves determining the size, shape and structure of soft wheat proteins. The submicroscopic structure of starch gels and the influence of thermal factors and hydrogen-ion factors during retrogradation is being investigated. Enzymology of wheat as related to germ damage in storage; unidentified factors in wheat germ oil; biochemical and physical processes occurring in stored grains; and physical quality of wheat in relation to milling quality and wheat quality are other problems receiving attention. A cooperative investigation with USDA attempts to improve the interaction of wheat gluten with dialdehyde starch.

Several aspects of processing technology are being investigated. One study explores the effect of chlorine on starch in the bleaching of wheat flour. The mode of action of chlorine on starch is receiving special attention. Factors influencing wheat conditioning and the effects of high voltage cathode ray irradiation on the chemical properties and biological value of wheat proteins are other processing techniques being investigated. Efforts continue. Cooperative research with USDA involves study of enzyme formation during wheat malting.

The use of wheat and wheat products as components of structural products is also under study. Advantage is taken of certain of the chemical and physical properties of wheat and wheat fractions.

Industry and other organizations including one state government conduct valuable research on utilization of wheat. The major research interest of wheat millers and processors is directed towards food uses of wheat. Probably less than 15 percent of their total research effort pertains

to development of new industrial uses. In this area, only a small amount of basic research is in progress, with the larger share of the effort being devoted to applied and developmental research on processes and products derived from wheat flour fractions, wheat starch and wheat gluten. Some cooperative work is performed in evaluation of processes and products developed by the Department. Except for such cooperative work, the exact nature of the products and processes investigated and the results are kept confidential by the companies or patented. Estimated annual expenditures by industry for research on industrial products from wheat are equivalent to approximately 5.0 professional man-years in basic research and 31.0 professional man-years in applied and developmental research on products and processes.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties

1. Characterization of wheat gluten proteins. Basic studies on the protein components of gluten as revealed by starch gel electrophoresis in the presence of a high concentration of urea have resulted in the following revision of our nomenclature for gluten proteins:

<u>Previous Designation</u>	<u>New Designation</u>
Alcohol-insoluble fraction of gluten	Glutenin
Alcohol-soluble fraction of gluten	Gliadin
Individual components:	
α_1 -gluten	Glutenin
α_2 -gluten	α_1 -gliadin
	α_2 -gliadin
β -gluten	β_1 -, β_2 -, β_3 - and β_4 -gliadin
γ -gluten	γ -gliadin
ω -gluten	ω -gliadin

These distinctions derive from observations that starch gel electrophoresis in the presence of concentrated urea resolved gliadin into eight components, whereas glutenin did not migrate. Sedimentation showed that glutenin was a mixture of many components with molecular weights ranging from about 50,000 to many millions. The weight-average molecular weight was 2 to 3 million. Cleavage of the disulfide linkages of glutenin gave uniform protein molecules having a molecular weight of 21,000. This observation shows that glutenin is composed of polymers of the small protein molecules held together by sulfur bonds. Gliadin components have molecular weights in the 40,000 range. Reduction caused no increase in components, suggesting that disulfide bonds in gliadin are mainly intramolecular.

Evidence was obtained that intermolecular association of wheat gluten through hydrogen bonding depends on the conformation imparted to the molecules by disulfide bonding. Thus, glutenin after reduction to cleave disulfide bonds showed a greater tendency to hydrogen bond than did native glutenin. Main sites for hydrogen bonding appear to involve primary amide groups. As 10 to 98 percent of the carboxyl groups in polyglutamic acid were converted to amide groups, solubility decreased in nonpolar solvents. The material finally dissolved only in solvents that break hydrogen bonds. An almost completely amidated polypeptide showed high crystallinity and β -conformation (X-ray patterns). When the polypeptide contained only 37 percent of primary amide groups (a value similar to that for gluten) the molecule could still assume an α structure. The information obtained contributes to our understanding of the behavior of wheat gluten and is basically important to physical and chemical modification of this material.

Optical rotatory dispersion data is in general agreement with our concept that glutenin is an expandable, randomly coiled polymer. However, there is definitely some oriented structure present that may be important to its properties. It may be possible to control association of protein molecules by altering the proportion of amide groups, and to control conformation by appropriate changes in disulfide linkages and pH. Reduction of all disulfide bonds in wheat gluten would produce a material much more nearly homogeneous in molecular size and structure and therefore more suitable for chemical modification.

2. Chemical reactions of wheat gluten. Deamidation of gluten in benzyl alcohol gave a partially benzylated protein yielding films having improved wet strength and water resistance. In contrast, films from a variety of native glutes had low wet strength and were brittle even after addition of plasticizers and crosslinking agents. The properties of benzylated gluten appear to be consistent with those of synthetic polybenzyl glutamate which gave flexible, water-resistant films.

Procedures were devised for reacting acrylonitrile with gluten proteins to quantitatively block sulfhydryl groups without affecting electrophoretic patterns. This reaction offers promise as a tool not only for studying structure but also for making useful derivatives.

Gluten derivatives having unique properties were prepared by converting the primary amide groups of the protein to methyl esters. Products had increased solubility in alcohol, and most or all of the peptide bonds were retained. The products were less soluble in the presence of salts than the intact gluten, indicating that primary amide groups are important to association of gluten molecules in water. Dimethylsulfoxide solvation of gluten allows single-phase reactions to be carried out in the presence of salts without precipitation. This

discovery greatly facilitates study of such reactions as deamidation, deamination and alkylation.

3. Wheat sterols. Although laboratory work on this contract project at Iowa State University was completed some time ago, the final report, received during the present reporting period, revealed some additional information of interest. Wheat bran was found to contain a phenolic compound, not present in the germ, having the empirical formula $C_{16}H_{30}O$. At least five apparently distinct sterols in addition to β -sitosterol were isolated from germ and bran and bran steroid fractions. One of these sterols was characterized as a dihydro- γ -sitosterol, but the structures of the others were not completely elucidated.

4. Synthetic polypeptides related to wheat gliadin. Numerous model polymers and copolymers, both linear and branched in type, were synthesized from selected, component amino acids of gliadin. Pertinent chemical and physical properties of these model polymers were determined. The information obtained has been applied successfully in the synthesis of a limited number of new, water-soluble, multichain polymers of gluten. This research is being conducted by the Weizmann Institute of Science, Rehovot, Israel.

B. Industrial Chemical Products

1. Acid-modified flour. The operating limits for producing a wide range of viscosity grades of modified flour by treatment in the dry state with acid have been established. The process has been scaled up in the laboratory from 200-gram runs to 7-pound runs. Because of more efficient distribution and mixing in the larger runs, a reaction time of only 1 to 2 hours was required to achieve the same results as were obtained in 6 to 8 hours in small runs. Sizing quality of the acid-modified flours from the large runs was equal to that previously found for the small-scale preparations. Heating dry, neutralized, acid-modified flour for 7 hours at 100° C. was found to greatly improve its performance as a coating adhesive for paper. Coatings prepared with this product had wax pick values of 7-8, as compared to 8 for the commercial reference coating adhesive and only 2 for the unheated acid-modified flour.

Contract work at the Institute of Paper Chemistry on the use of hydroxyethylated acid-modified wheat flour in paper has been completed. Final conclusions were that acid-modified wheat flour, with or without hydroxyethylation, gave good dispersibility and paste viscosity properties. Surface-size tests showed effectiveness equivalent to the best commercial starch size in strength and optical properties of the paper.

In view of these favorable results, engineering studies were undertaken on the preparation of acid-modified (AM) and hydroxyethylated acid-modified (HEAM) flours in the pilot plant for larger scale evaluation at the Forest Products Laboratory. The pilot-plant equipment was modified to permit preparation of 30- to 40-pound batches and to obtain better control of the process. The pilot-plant production of AM and HEAM flours showed that product characteristics could be duplicated from run to run, and confirmed results from previous laboratory preparations. Results of small-scale sizing trials conducted at the Northern Division compared favorably with those for a good quality commercial hypochlorite-oxidized starch size.

2. Flour sulfates. A series of flour sulfates was prepared by treatment of flour with a novel polymeric sulfating agent (polyvinylpyridine-sulfur trioxide complex). The most distinctive characteristics of the sulfated flours are their high degree of dispersibility (82-98 percent), high viscosity (up to 4,300 cps. for 2-percent dispersions), and high clarity. Sulfated flours with low degrees of substitution (DS) adsorb to pulp fibers whereas those of high DS do not. A number of sulfated flours have been prepared for evaluation as beater additives.

3. "Cereal-pulp" products. Xanthates of starch, wheat flour, ground wheat, and wheat bran with degrees of substitution from 0.05 to 0.5 are coupled nearly quantitatively to pulp fibers in a matter of seconds when oxidants are added. Low-cost oxidants such as chlorine and nitrogen dioxide are satisfactory, and high wood pulp consistency appears to favor retention. Neutral to acidic conditions give best oxidative crosslinking. Papers were prepared containing up to 50 percent of these "cereal pulps." Improved strength properties, including 300-percent increase in permanent wet strength, were realized. A number of other types of paper products containing from 2 to 40 percent of cereal pulps have been prepared. These include liner and corrugating board for boxes, insulating and hard boards, and newsprint and grease-proof papers. Conventional equipment was used and the products compared favorably with commercial equivalents.

Cereal-pulp products look promising. Low levels of xanthation (degree of substitution of 0.1) appear sufficient, requiring about 4 percent added chemical in the xanthide. Technical-grade carbon disulfide is 5-1/4 cents per pound and sodium hydroxide is 3 to 4 cents. With starch or flour at 6 cents per pound, the cost for materials would be 6.6 cents per pound. Unbleached sulfate pulp is 6.75 to 7.0 cents per pound. How cereal pulps will fit into the 35-million-ton-per-year paper and paper products market is a question that will be answered only after much further research and development work. Many variables in the process, and the relation of these variables to product properties, need study.

4. New copolymers from wheat flour. Contract research at Stanford Research Institute has shown that a variety of graft copolymers can be prepared in yields up to 98 percent from starch and monomers such as methyl methacrylate, acrylamide, and acrylonitrile. Some of these products had sharp melting points, while others softened with heat and probably could be molded. Some were soluble in organic solvents, others in water. Certain of the soluble graft copolymers appeared to be film formers. Type of product was affected by ratio of starch to monomer, type of initiator (redox systems, ionizing radiation, peroxides, azobisnitriles, UV plus photosensitizer), solvent, nature of monomer, and physical state of the starch. A freeze-thaw treatment of starch was found to be about as effective as ceric ion for generation of free radicals. A significant concentration of free radicals was found to remain "captured" after irradiation with a cobalt-60 source. This research is directed towards the ultimate production of new polymeric products from wheat flour fractions.

5. Adhesives from gluten and dialdehyde starch (DAS). Contract research at Iowa State University involves investigation of the reaction of DAS with wheat gluten as a basis for improving adhesive properties of gluten. Initial effort has been directed towards study of dispersants for DAS and vital gluten to provide information needed for investigation of the DAS-gluten reaction in solution. Adhesives have been prepared from solutions of DAS and wheat gluten in various solvents. Combinations were found that gave bonds of good tensile strength, especially when the DAS was dispersed in sodium bisulfite solution.

C. Processing Technology

1. Conditioning and dry milling of Pacific Northwest wheats. Long patent flours prepared from Pacific Northwest hard and soft wheats were fractionated to yield a wide variety of high- and low-protein fractions. Brevor variety (soft white winter wheat) yielded the widest range of fractions--from 1.3 to 25.1 percent protein. Reprocessing low-protein fractions from these PNW wheats yielded fractions containing as little as 1.0 percent protein (35 percent of the original flour from Brevor SWW), and all of the other varieties tested (Omar WC, Burt HWW, and Rio HRW) yielded fractions containing under 3.5 percent protein. Both unmodified samples of the low-protein fractions and samples modified by treatment with acids or other methods show promise as industrial starches for use in manufacture of paper and gypsum board. Baking tests at the Western Utilization Research and Development Division showed that the value of the high-protein fractions for fortifying bread flour decreased in the order: Brevor SWW, Rio HRW, Burt HWW and Omar WC. Fractions were less suitable than original flours for cookies, but regrinding improved all flours for cakes.

2. Conditioning and dry milling of hard red winter wheat. In fine grinding and air classification of wheat flour, hard wheats do not yield fractions as low in protein as do soft wheats. Because surplus wheat production is comprised mainly of the hard wheats, methods are needed for effective separation of hard wheat flours into high-protein fractions for edible use and low-protein fractions for industrial use. Concho variety of hard red winter wheat was given a variety of pre-treatments to determine their effects on classification. Fractionation of standard milled flour from this wheat yielded a fraction of 6.6 percent protein. Conditioning the wheat with indirect heat permitted separation of a lower protein fraction: 5.9 percent from 150° F. treatment, 5.6 percent from 190°. Gluten was damaged somewhat in the 150° treatment and drastically at 190°. After repeated drying and wetting cycles, a fraction was separated at 5.9 percent protein. By repeated freezing and thawing a low of 5.1 percent protein was reached, but the flour was of reduced elasticity; also ash content of the flour was increased. The low-protein fraction from Wichita HRW wheat was reprocessed after various treatments including heat, defatting, enzymes, sulfur dioxide and ammonia. Variations were also made in the regrinding and reclassification operations such as varying moisture content and grinding intensity, and use of fluid energy mill instead of pin mill. The lowest protein fraction from any of these treatments still contained 5.3 percent protein. In fractionation of long patent flours from Comanche, Wichita and Triumph HRW Kansas wheats, Triumph responded best, yielding a fraction containing 4.3 percent protein.

Variations in conditioning treatment with HRW wheat have not proved effective in giving flours which will yield a fraction containing a maximum of 3 percent protein on air classification. It is apparent that new approaches and concepts will be needed to solve this problem. Microscopic studies on the flours show there are definite differences in starch-protein combinations in hard and soft flours. Use of the electron microscope for evaluating the effects of processing on the binding of starch and protein in wheat should greatly assist in determining whether separation of such a fraction from HRW wheat flour is inherently possible. Inability to produce a directly usable industrial starch fraction from hard wheat flours does not preclude possibilities that air classification may yield fractions having superior properties for chemical modification such as xanthation.

3. Enzymes in malted wheat. Contract work at Kansas State University on variations in amylase and protease activity of malted wheat induced by chemicals has been completed. Potassium gibberellate (GA-K) was the most effective chemical for increasing the enzyme activity of malts. Optimum concentration appeared to be 0.005 percent GA-K in the steep liquor. The treated malts had enzyme activity equivalent to control malts germinated 1-3 additional days. Studies of the effects of mixtures of GA-K with other chemicals revealed a few instances of

synergistic response, an observation of some theoretical significance. Use of the gibberellic acid treatment in wheat malting should be practical in view of the fact that such treatment is being practiced in the barley malting industry. Under a new contract at Kansas State University, investigations have been initiated on enzyme precursors and the mechanism of formation of amylase and protease during the early stages of germination of wheat. The objective is to obtain basic information for exploitation of enzyme development and action on the grain kernel during moisture conditioning of the grain for dry milling, especially by fine grinding and air classification of hard wheats, to allow better separation of protein from starch. Significant results have not yet been obtained.

4. Quantitative measurement of wheat conditioning variables. This research, which is being conducted at the Cereals Research Station, Research Association of British Flour Millers, St. Albans, England, is still in its preliminary stages. One interesting finding has, however, been reported. This is that appreciable amounts of scutellum and aleurone are concentrated in the fine fraction obtained by air classification.

D. Wheat Structural Products

1. Puffed wheat particle board. Extended studies have been conducted on experimental preparation, measurement of physical properties, and analysis of economic factors involved in the preparation of insulating and hard boards from commercially available puffed wheat particle board have been concluded. Insulation-type puffed wheat particle board of density up to 20 pounds per cubic foot has no advantage over similar products made from wood or bagasse. Adverse factors are (1) higher costs of raw material, puffing, resin binder, and manufacture into board, (2) lower strength and rupture values, (3) poor water resistance, (4) shrinkage of puffed kernels on spray application of urea-formaldehyde resin, (5) inherent weakness of puffed kernel, (6) vulnerability to microorganisms, insects, and rodents, and (7) no apparent advantage over puffed corn or sorghum. Higher density boards would require more raw material resulting in even larger raw material cost per square foot. Consideration was given to the use of puffed wheat to produce the resilient core in boxboard. Experimental attempts were made to cement puffed wheat kernels between two kraft liner boards. The wheat-cored boxboards made were not satisfactory from the standpoint of physical properties, and costs for puffed wheat alone were not favorable over the use of paper corrugating medium. It was concluded that puffed wheat does not offer much promise as a raw material for structural board or boxboard. Modification of wheat or wheat products by chemicals before incorporation into structural products may lead to desirable properties. This research has been completed.

2. Structural foams from gluten and flour. Research on structural foams from chemically unmodified gluten and flour has been completed. Results obtained in the last phases of the work showed that, although promising foams could be obtained from vital gluten, useful products did not result from flour. Use of calcium chloride to gelatinize starch in flour without devitalizing the gluten gave initially encouraging results, but this approach was dropped because the calcium chloride could not be removed readily or inexpensively from the final product. Preliminary results with xanthated flour (cereal pulp), a highly viscous material as is xanthated starch, suggest that these materials might be economical sources of foams. Considerable knowledge and technology on the foaming properties of wheat flour have been obtained. Application of this knowledge as opportunities arise in future investigations on industrial applications of wheat flour could point the way to development of new foamed products.

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CORN, SORGHUM, AND OTHER FEED GRAINS
IMPROVED INDUSTRIAL, FEED AND FOOD PRODUCTS
Northern Utilization Research and Development Division, ARS

Problem. Abundant quantities of corn, sorghum, and other feed grains are now available beyond those amounts required to satisfy current needs. Both domestic consumption and export potential of these grains could be increased by development of new products for use by industry or of improved foods and feeds. Industrially, increased use of corn and sorghum will be mainly dependent upon increased markets for starch. However, flours derived from these grains are mixtures of starch, protein, and minor amounts of other components. Such mixtures have promise as raw materials for conversion to adhesives, water-soluble coatings, plastic materials, and related products that should have properties and uses different from related products derived from refined starch or wheat flour and that should contribute independently to increasing industrial markets. Isolated protein components of corn and sorghum flours should be suitable raw materials for production of useful resins and films. To achieve these utilization goals, more information is needed on basic physical and chemical properties and reactions of these flours, on the properties of component lipids, waxes, and proteins and their possible interactions with starch, and on the use of fine grinding and air classification and other new milling techniques for obtaining milled products having the most advantageous properties as industrial raw materials.

Because of the growing emphasis on increasing meat production, there is need for processes to obtain improved feed products such as high-protein feeds, mill feeds, feed concentrates, and feeds with high oil content. Such improvement could be achieved through research to obtain better knowledge of the biologically and nutritionally important constituents of corn, sorghum, and oats, to evaluate present, and to develop improved, milling and processing methods, and to ascertain the effects of such methods on the nutritional qualities of the products. In addition, because of the world shortage of protein in human nutrition, this research could enhance the export value of these grains by providing the necessary basis for development of high-protein and other food products that would be acceptable in foreign markets.

USDA PROGRAM

The Department has a continuing long-term program involving analytical and organic chemists, chemical engineers and structural biologists engaged in basic studies of the components of corn and sorghum and in application of the new knowledge gained to the development of improved processing technology leading to more effective utilization of these cereal grains.

The Federal scientific effort for research in this area totals 9.0 professional man-years. Of this number 3.2 are devoted to chemical composition and physical properties and 5.8 to processing technology.

Research on chemical composition and physical properties is conducted at Peoria, Illinois, and involves investigations of physiologically active nonprotein nitrogen substances in corn and of carotenoid pigments of corn, corn milling fractions, and yellow endosperm sorghum. A portion of the effort on carotenoid pigments is cooperative with Crops Research Division and is directed to development of corn and sorghum varieties having high carotenoid content. Such varieties are needed for improved food and feed products and to enhance the competitive position of U. S. corn in international trade.

During the reporting period specific studies of the pellagragenic factor of corn were deemphasized in favor of a broader and more general investigation of nonprotein nitrogen substances. Cooperative studies with Iowa State University on vitamin and amino acid content of new oat strains were discontinued. Contract research on the nature of gums occurring in oats was completed.

Processing technology research, also conducted at Peoria, Illinois, involves pilot-plant studies of conditions and methods for increasing the yield of oil and grits by dry-milling processes. Effects of processing variations on industrially and biologically important components of corn are determined.

The Department also sponsors research (7.1 professional man-years) in this area conducted under grants of PL 480 funds to the following foreign institutions: Research Association of British Flour Millers, St. Albans, England, for studies of antioxidants occurring in oats (2.0 professional man-years); National Institute of Agronomic Research, Paris, France, for basic studies of the physical chemical properties of corn zein (3.0 professional man-years); and Weizmann Institute of Science, Rehovot, Israel, for research on synthetic polypeptides with amino acid compositions related to zein (2.1 professional man-years). These lines of work are under the subheading chemical composition and physical properties.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Stations in 1961 reported a total of 0.2 professional man-year devoted to chemical composition and physical properties. Emphasis is placed on extraction and characterization of corn protein.

Industry and other organizations also conduct interesting and valuable investigations in this research area. Essentially all of the industrial research on developing new and improved industrial and food products from corn and its components, exclusive of refined corn starch,

is believed to be conducted by corn dry-milling companies. Applied and processing research on feed products is largely conducted by corn wet-milling companies and to some extent by the dry millers. Food manufacturers and brewers endeavor to improve products based on existing materials available from corn to meet competitive situations or to solve other problems incidental to company operations; however, except for certain food manufacturers and brewers who also engaged in corn milling, no research to derive or develop new materials from corn for use in their products is believed to be involved. Of the dry-milling companies, less than one-fourth are large enough to maintain a significant research program. Their largest effort is directed to process and application studies for food and brewing uses of corn. Only a small amount of basic research is conducted in this area. Interest has been increasing in industrial markets for corn flour and protein, and a number of companies are conducting applied and developmental research in this field. No basic research appears to be in progress on industrial products from corn flour. Industrial research on sorghum is small and is directed towards processing for industrial uses. Several companies have cooperated in evaluation of products and processes developed by the Department. Except for cooperative work, the exact character and results of their research are kept confidential by the companies or patented. Estimated annual expenditures for research in these areas are approximately 5.0 professional man-years in basic research on food products, 45.0 professional man-years in process and application research on foods from corn, 20.0 professional man-years in applied and processing research on feeds, and 25.0 professional man-years in applied and developmental research on industrial uses of corn and sorghum.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties

1. Nonprotein nitrogen substances of corn. A new chromatographic procedure has been developed for separation and determination of low-molecular-weight nicotinic acid derivatives present in extracts of corn. The method can be used for analysis of numerous extracts of various corn grain fractions and milling products and for ascertaining the distribution of such components in grain and changes that may occur during processing.

Chromatography of the bound niacin substance on alumina columns showed that pigment is not an integral part of this substance. The molecule is, however, a complex structure containing carbohydrates, amino acids and other components as well as bound niacin.

Forty-five percent of the free amino acids of corn is in the germ. One-third of the nitrogen in steep liquor is nonprotein nitrogen, more than can be accounted for from the nonprotein nitrogen in whole grain.

Analyses were therefore performed for all of the free amino acids in whole corn; germ, endosperm and bran fractions; and corn steep liquors. Individual amino acids of acid hydrolyzates of corn steep liquors were also determined. A component chromatographically similar to betaine was observed in whole corn, endosperm and germ. Trigonelline and choline levels in corn steep liquor were higher than in the grain. The results of the analyses show that bacterial and enzymatic hydrolysis of corn protein and further modification of the liberated amino acids takes place during steeping. Commercial steeping appears to extract effectively nonprotein nitrogen components from corn.

2. Corn and sorghum carotenoids. Yellow corn and sorghum, which owe their color to carotenoid pigments (carotenes and xanthophylls), have enhanced value as feed for cattle and poultry. Thus, carotenes are the precursor of vitamin A and in cattle feeding are the source of yellow color in milk and body fat. Xanthophylls impart the yellow color to egg yolks (the basis for commercial grading) and to the skin and fat of broilers and fryers. The present project was undertaken to investigate differences in the amount and chemical identity of individual carotenoid pigments of yellow corn and milled fractions and of yellow grain sorghums in order to provide information on variations among grain varieties and milled fractions and on changes during processing that could influence the commercial value of these feed-stuffs.

An improved chromatographic procedure was developed for determination of total carotenes and total xanthophylls in corn and sorghum. Statistical evaluation showed that the method would be suitable for screening purposes, even for samples available in only limited quantities. Application of the method to 110 samples of hybrid and inbred corn showed considerable variation in the range of carotenes (0-5 p.p.m.) and xanthophylls (0-45 p.p.m.). Argentine flint corn contains up to 60 p.p.m. xanthophyll compared to yellow dent hybrids with 25 p.p.m. Initial studies on carotenoids in wet- and dry-milled fractions of corn showed that variation of carotenoid content of two samples of gluten was of the same magnitude as that in the parent whole corns processed. Carotenoid content of gluten feed and meal appeared to depend on the type and amount of materials blended during processing.

Cooperative studies with Crops Research Division have correlated the parental source of the yellow genes with xanthophyll contents of first-cross progeny. Carotenes and xanthophylls appear to be independently inherited, precluding estimation of xanthophylls from carotene content. An unsupplemented poultry ration containing 60 percent corn will contain the desired level of 25-27 p.p.m. xanthophyll if the corn contains 42-45 p.p.m. or nearly twice the normal amount; the xanthophyll content of pure lines available for hybrid combination are within this range.

Grain from the best yellow endosperm sorghum examined to date contained only 5.6 p.p.m. total carotenoids as compared to yellow corn (24 p.p.m.) grown in the same area. Grain sorghum exposed to weathering after pollination retained only 50 percent of the carotenoids present in protected seed heads. The low carotenoid content of available varieties of sorghum and the adverse effects of weathering constitute major problems in the program for breeding high carotenoid sorghums.

3. Oat gums and antioxidants. Significant interpretations of previously reported data on oat gums were revealed by the final report on this contract project at the University of Minnesota. β -D-glucan, the main viscosity producing carbohydrate, was found to possess new features of chemical structure for this class of carbohydrates. Whereas most of the D-glucose units are joined by alternating β -1,4 and β -1,3 linkages, a few segments of chains contain two to four consecutive β -1,3 linkages and others two or more consecutive β -1,4 linkages. The gum-degrading enzyme preferentially attacked the consecutive β -1,3 linkages, which also appeared to be involved in the degradation that occurs during manufacture of rolled oats.

At the Cereals Research Station, Research Association of British Flour Millers, St. Albans, England, automatic oxygen absorption apparatus has been developed to permit the measurement of induction periods on as little as 0.1 g. fat. This apparatus facilitates the measurement of the effects of antioxidants upon lipid oxidation and helps clarify the quantitative relationship between oxidation and organoleptic rancidity. A major antioxidant present in raw oats has been isolated from the grain and characterized. It was shown to be an ester consisting of one mole each of ferulic and caffeic acids and 2,6-hydroxyhexacosanoic acid. These developments are significant contributions to the problem of stabilization of lipids in baked oat products for retention of flavor.

4. Synthetic polypeptides related to zein. Numerous model polymers and copolymers, both linear and branched in type, were synthesized from selected, component amino acids of zein. Pertinent chemical and physical properties of these model polymers were determined. The information gained from these studies has been applied successfully in the synthesis of a limited number of new, water-soluble, multichain, polymers of zein. This research is conducted at the Weizmann Institute of Science, Rehovot, Israel.

B. Processing Technology

1. Corn dry milling. A statistically planned series of experiments has provided data on the effects of the following variables on yield and characteristics of degerminator products: first temper moisture, tail gate loading, feed rate, size of screen perforations, throughput,

and rotor speed. This information is important to millers in showing how to achieve the most efficient use of the degerminator.

A procedure for shortening temper time was discovered. Corn was immersed in water for 1 minute under a vacuum of 5 inches of mercury and 9 minutes at atmospheric pressure and drained 5 minutes. Degermination gave increased yield of $-4 + 6$ grits and decreased yield of $-6 + 8$ grits. Both fractions contained less oil. Except that degerminator throughput was 20 percent lower, overall results were superior to, or compared favorably with, those obtained by a conventional procedure based on tempering times of 3.25 hours. However, response varied materially with the source and age of the corn. A patent has been allowed on this process and industry has expressed considerable interest.

Caustic tempering gave reduced oil content in milled products with some lots of corn but not with others. Hull release and polish were, however, improved in every instance.

Additional rest time after conditioning is needed to obtain high degerminator capacity with some varieties of corn that have been vacuum-tempered. Combined caustic and vacuum tempering improved oil recovery to the level of conventional tempering and gave better quality product.

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HIGH-AMYLOSE CORN
INDUSTRIAL UTILIZATION

Northern Utilization Research and Development Division, ARS

Problem. Varieties of corn have been achieved genetically that contain greatly increased amounts of amylose. Amylose, the linear fraction of starch, possesses film- and fiber-forming properties not available in ordinary starch which contains only about 27 percent of this component. Because the unique properties of amylose open areas of utilization closed to ordinary starch, the potential industrial value of this new crop is very high. Several problems must be solved, however, to realize this potential.

For high-amylose starch to have substantially improved properties as a raw material in comparison with ordinary starch, it should contain at least 80 percent of amylose. Although a number of breeding samples have contained as high as 75-80 percent of amylose, only varieties containing 50-60 percent have so far been commercially available. Even at this amylose level, however, over 4 million pounds of high-amylose starch from first commercial plantings were utilized by industry in 1961. Although breeding is the task of the geneticist, utilization research is needed to provide information on amylose content, on changes in quantities and properties of the amylose, amylopectin, and other components such as oil and protein, and on milling characteristics of breeding samples in order to insure availability of satisfactory varieties.

A second problem is development of methods for economical isolation of pure amylose from high-amylose starch. For some anticipated uses, nearly pure amylose may be required for optimum properties. Although achievement of 80-percent high-amylose starch appears certain, it may not be possible to obtain much higher levels through breeding. Success in devising efficient fractionation methods will depend upon availability of adequate basic information on freeing and separating amylose from remaining starch components.

Finally, to insure utilization of the potentially large volume of high-amylose starch that could eventually become available, more information is needed on the chemical and physical properties of amylose and high-amylose starch and on methods for converting them economically to desired products. Success in this research could lead to an estimated consumption of over 600 million pounds of high-amylose starch by 1975 in films, fibers, plastics, coatings, and related products to which the linear character of amylose could make contributions.

USDA PROGRAM

The Department conducts a long-term, continuing program of research involving analytical, organic and physical chemists, structural biologists, and chemical and mechanical engineers who are engaged in basic and applied research designed to increase knowledge of the properties and reactions of amylose and other components of high-amylose corn and to utilize this knowledge in development of attractive industrial applications for amylose and high-amylose starch.

The Federal scientific effort for research on utilization of high-amylose corn totals 20.5 professional man-years. Of this number 12.4 are devoted to chemical composition and physical properties; 7.6 to industrial utilization; and .5 to processing technology.

Investigations on high-amylose corn are conducted at Peoria, Illinois. Research on chemical composition and physical properties involves study of amylose content of breeding samples, starch and starch granule composition, structure and properties; and composition and properties of proteins and other components of high-amylose corn. Research on industrial utilization is devoted to studies on separation of amylose from high-amylose starch, and formation and properties of amylose films. During the reporting period contract research on evaluation of high-amylose starch in paper was completed. Research on processing technology involves milling studies on breeding samples and histological studies on high-amylose corn. During the reporting period intensive examination of milling properties of high-amylose corn was discontinued and such work is now performed on an "as needed" basis. Studies on amylose content and milling properties of breeding samples assist geneticists in developing varieties of high-amylose corn having increased amylose content and improved milling properties. Cooperation with Field Crops Research Branch, Crops Research Division, is maintained in conducting these studies.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Stations in 1961 reported a total of 2.8 professional man-years devoted to chemical composition and physical properties. Characterization and chemical determination of the amylose content of starch from newly developed lines and varieties of corn is an important aspect of station research which supports corn breeding programs. Station researchers are sampling several open-pollinated varieties of corn to determine the natural variation which occurs in amylose content.

Industry and other organizations also perform valuable research involving high-amylose corn. Because of the present experimental nature of the crops, research on uses of starch from high-amylose corn is conducted by a very small number of companies who have contracted with

farmers to have small acreages of the crop grown for their use. The exact character of the research conducted on high-amylose starch and the results are kept confidential by the companies or patented. The Corn Industries Research Foundation supports basic research on high-amylose starch at the Northern Division (approximately .7 professional man-year). The results of this research are, of course, made public. Estimated annual expenditures by industry for research on high-amylose corn starch are equivalent to approximately 4.0 professional man-years in basic research and 6.0 professional man-years in applied and developmental research.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties

1. Amylose content of breeding samples. During the reporting period 36,292 samples of high-amylose corn were analyzed. These were supplied under Memoranda of Understanding by the Bear Hybrid Corn Company, by the Missouri Agricultural Experiment Station and by Crops Research Division at the Missouri Station. Amylose content for nearly 200 of these samples was over 75 percent and the highest value was 79.3 percent. (In this report percentages of amylose refer to apparent values determined by iodine titration. True amylose content, measured by quantitative fractionation, averages about 80 percent of the apparent value.) In 1961, over 1,000 acres of class 5 (55-60 percent) high-amylose corn was planted, marking commercialization of this new crop. Class 6 (60-70 percent) high-amylose corn is reported to be ready for commercialization. Class 7 (70-80 percent) is expected to be ready for commercialization by 1965.

2. Properties of components of high-amylose starch. Fractionation of a series of high-amylose corn starches by the solvent pretreatment-alkaline extraction procedure was rechecked, useful variations of the procedure were incorporated, and original findings were confirmed: (1) Amyloses from dent and high-amylose corn starches are comparable in iodine binding power and molecular weight; (2) by iodine binding and β -amylase conversion, the amylopectins of high-amylose corn starches show increased length in the external branches when compared with the dent corn amylopectin.

In laboratory studies on fractionation of high-amylose starch by aqueous extraction-sedimentation procedures after hydration-freezing pretreatment, recent findings indicate that (a) restoration of normal moisture content after drying starch increases yield and purity of amylose; (b) corn steeped in aqueous sodium sulfide or diethyl dithiocarbamate yields amylose of high purity (90-92 percent) than corn steeped in aqueous sulfur dioxide (85-88 percent); (c) pretreating starch in an autoclave (105-120°) greatly increases rate of

liberation of amylose; and (d) for all types of starch available three extractions at 100-101° are needed to recover 93-95 percent of the amylose present.

An improved medium (2M lithium bromide plus 4M guanidinium chloride) has been found for dispersing amylose, amylopectin and other starch fractions for molecular-weight determinations. Crystallinity and density of granules of potato starch and of two high-amylose corn starches decreased as amylose content increased.

3. Proteins of high-amylose corn. Research has been undertaken to obtain information on differences among proteins of corn containing varying amounts of amylose. The first phase of the work involves efforts to characterize proteins of ordinary dent corn. The components of native and commercial zein were separated with the aid of agar- and starch-gel electrophoretic techniques. Highly significant differences in composition were demonstrated. Native zein showed three major and nine minor components. Some material remained in evidence at the origin of the electrophoretic pattern. In contrast, commercial zein showed only five components with little material at the origin. Reductive cleavage and alkylation or performic acid oxidation of the disulfide bonds of native zein gave products that behaved electrophoretically like commercial zein.

Gel electrophoretic analysis of α - and β -zein showed that α -zein contains four components whereas β -zein does not migrate. After reduction of disulfide bonds, α - and β -zein each contain four components having correspondingly similar mobilities. In addition, reduced β -zein contains two fast-moving components not present in α -zein. Native zein containing at least five electrophoretic components gave an average molecular weight of 44,000 by sedimentation. After cleaving disulfide bonds, a molecular weight of 20,000 was obtained, which agrees with the minimum molecular weight calculated from amino acid composition of whole zein. The globulin fraction of whole corn was resolved into 17 components by starch gel electrophoresis.

These observations show that the slower moving minor components of native zein are aggregates derived by disulfide bonding of the major component proteins and that, in commercial zein, sulfur dioxide used in steeping the corn has cleaved the disulfide bonds originally present.

B. Industrial Utilization

1. Fractionation of high-amylose starch. In recently undertaken engineering studies, either the freezing pretreatment or a variety of mechanical and chemical pretreatments of 67-percent high-amylose starch followed by aqueous leaching gave similar results: 53-percent

recovery of 84-86-percent pure amylose. Fractionation by complexing with capric acid gave 86-percent yields of 83-percent pure amylose.

2. Amylose films. Wet-tensile strength was increased materially when film was immersed in hot saturated ammonium sulfate. The film, in contrast to its behavior in water, remained intact at temperatures up to the boiling point of the bath (107° C.) while partial dehydration took place. Immersion at this temperature for 15-30 seconds resulted in an increase of wet-tensile strength from about 200 pounds per square inch cross-section to 400-500 pounds. At the same time the water-binding capacity of the film was permanently reduced from approximately 75 percent to about 60 percent (based on the weight of blotted film vs. bone-dry weight). Lesser, although still useful, effects were attained at a temperature of 85° C.

Extrusions embodying the above dehydrating technique have resulted in improved operational speed. There is still need, however, for effecting dehydration more rapidly or, alternatively, for supplying interim strengthening while dehydration is proceeding.

3. High-amylose starch in paper. Contract research at the Institute of Paper Chemistry on evaluation of high-amylose starch in paper was completed. One unmodified and eight modified samples of high-amylose starch were evaluated as beater adhesives, fiber deflocculants, surface-sizing agents and pigment-coating adhesives. The most consistently effective material was a 6.47 percent hypochlorite-oxidized starch. All samples were ineffective as deflocculants. Alkali-dispersed unmodified high-amylose starch gave excellent strength properties as beater additives and surface sizes. For certain specific areas and conditions of application, high-amylose starch samples were somewhat superior to the corresponding ordinary starch product.

C. Processing Technology

1. Wet-milling high-amylose corn. During the past 3 years, processing properties of available samples of high-amylose corn were compared with those of ordinary dent hybrids. Variations in milling characteristics of different samples of high-amylose corn were found. These variations appeared to be related to the genetic history of the samples, and have led to efforts by geneticists to breed milling quality into new strains. As a result, there is promise of new strains of high-amylose corn with greatly improved milling quality. Improved millability was observed for samples of amylomaize varieties bred to contain the so-called "milling factor" (M). In the absence of M, protein content may be an influencing factor but amylose content is not.

Present analytical methods indicate that high-amylose corn contains less starch but more protein and oil than dent corn. However, discrepancies were observed that suggest that conventional analytical

methods may not be suitable for high-amylose corn. Further investigations are in progress.

High-amylose corn was found to have two detrimental milling characteristics that need to be improved by selective breeding:

- (1) Starch contains a greater percentage of small starch granules than does dent corn; these small granules are lost in the washings or remain in the gluten resulting in lower starch recovery.
- (2) Kernels of high-amylose corn swell from 50 to 100 percent more during steeping than do ordinary corn kernels, giving a softer steeped grain requiring larger tanks for equal production capacity.

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WHEAT AND CORN

FERMENTATIVE CONVERSION TO NEW INDUSTRIAL, FEED AND FOOD PRODUCTS Northern Utilization Research and Development Division, ARS

Problem. By fermentation of cereal grain substrates, new products can be obtained that are not readily available by other means and have promising potential for industrial, agricultural, and food uses. Processes now under development, if brought to successful conclusion, could lead to increased consumption of an estimated 40 million bushels of grain for fermentative conversion to stable viscosity agents for secondary petroleum recovery by flooding of spent oil wells, to new organic acids and enzymes for industrial use, to feed supplements, and to effective biological insecticides and other pesticides that are harmless to man. In addition, there are good possibilities for utilizing fermentation processes to produce new food products that should promote foreign use of U. S. grains.

To accomplish these objectives and to realize the full potential of fermentative techniques for increasing utilization of grain, a broad program of exploratory research is required to find and identify through taxonomic studies species of organisms producing potentially valuable products, to isolate high-yielding strains or develop them by mutation, hybridization or genetic selection, and to develop basic information on culture media, special nutrients, and other factors required for optimum growth of microorganisms and maximum yields of desired products. Continued maintenance and expansion of a collection of pure cultures of well-characterized organisms is necessary for this research. For successful translation of laboratory results into commercially useful processes, more information is needed on new techniques of fermentation, on development of economical methods of growing organisms and handling fermentation processes on a large scale, and on special procedures for efficient isolation and purification of products from fermentative reaction mixtures. Finally, the most appropriate end uses for products must be identified and information obtained on product evaluation and development.

USDA PROGRAM

The Department has a long-range continuing program involving analytical and organic chemists, biochemists, microbiologists, systematic biologists, and chemical engineers engaged in basic research on microorganisms and microbiological reactions and products and in application of both known and newly discovered principles to the development of practical fermentation processes for conversion of cereal grain substrates to useful chemical and biological products.

The Federal scientific effort in this area of research totals 46.2 professional man-years. Of this number 15.3 are devoted to basic research on fermentation processes; 17.7 to industrial chemicals; 9.9 to biological pesticides; and 3.3 to feed and food products.

Basic research on fermentation processes conducted at Peoria, Illinois, (15.3 professional man-years) includes study of taxonomy of molds, yeasts and bacteria; factors affecting viability of microorganisms; and microbiological reactions and products. Basic to these investigations and to the Division's entire research program on fermentation is assembly and maintenance in pure culture of a large collection of agriculturally and industrially important microorganisms. Much of the research on microbiological reactions and products is conducted by the Pioneering Laboratory for Microbiological Chemistry. During the reporting period exploratory research on microbial hydroxylation of unsaturated fatty acids was discontinued. General studies of the taxonomy of actinomycetes and of yeasts of the genus Hansenula were completed.

Research at Peoria, Illinois, on industrial chemicals (17.7 professional man-years) involves fermentative production of microbial gums, organic acids, and other products for use in the chemical industry. During the reporting period research on six selected microbial polysaccharides was completed as was work on microbial deamidation of wheat gluten and microbial production of polyglutamic acid from gluten. Also, contract research was completed on development of methods for isolation of α -ketoglutaric acid from fermentation liquors.

Research at Peoria, Illinois, on biological pesticides (9.4 professional man-years) is devoted to studies on biological insecticides for Japanese beetle, other insect control agents and plant antibiotics. Investigations on biological insecticides for Japanese beetle and on other insect control agents is cooperative with Entomology Research Division and Plant Pest Control Division. Research on plant antibiotics involves cooperation with Crops Research Division. A research contract (.5 professional man-year) is in effect with Michigan State University, East Lansing, Michigan, for study of factors important to large-scale propagation of Japanese beetle pathogens. During the reporting period broad screening investigations of microbial plant antibiotics and specific studies of F-17 antibiotics were terminated in favor of restricted screening for antibiotics showing activity against a selected group of plant pathogens that can be cultured in the laboratory.

Research at Peoria, Illinois, on feed and food products (2.8 professional man-years) involves study of production of microbial carotenoids suitable for feed supplements. A research contract (.5 professional man-year) with Michigan State University, East Lansing, Michigan, concerns evaluation of biological availability of fermentative β -carotene when fed to poultry and swine.

The Department also sponsors research in the fermentation area (23.4 professional man-years) conducted by foreign institutions under grants of PL 480 funds. Basic research on fermentation processes (15.0 professional man-years) involves grants to the National Institute for Agronomic Research, Madrid, Spain, for collection of new species of yeast (2.0 professional man-years); University of Helsinki, Finland, for basic studies on organic phosphorus compounds of yeast (3.0 professional man-years); University of Milan, Italy, for basic studies on the metabolic pathway to 2-ketogluconic acid in Acetobacter species (2.8 professional man-years); University of Allahabad, India, for collection of new Mucorales species (2.1 professional man-years) and studies on survival of lyophilized microorganisms (2.1 professional man-years); and University of Durham, Newcastle-upon-Tyne, England, for investigations of sugar phosphate derivatives in molds (3.0 professional man-years). Research on industrial chemicals (4.4 professional man-years) involves a grant to Superior Institute of Health, Rome, Italy, for studies on foaming in anaerobic fermentations. Research on feed and food products (4.0 professional man-years) involves a grant to the "Giuliana Ronzone" Scientific Institute of Chemistry and Biochemistry, Milan, Italy, for research on production of vitamin B₁₃.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Stations in 1961 reported a total of 2.2 professional man-years under the subheading biological pesticides. One program involves basic work directed toward developing information on the physiology of molds which may be of industrial importance. Another program involves characterization of amino acid addition products isolated from plant materials.

Industry and other organizations conduct a large program of research in the area of fermentation. In the field of industrial chemicals, fermentation acids are usually manufactured from cheap foreign molasses when available. However, production of some acids requires cereal carbohydrate, and all common acids can be made from this substrate. Grain products and byproducts are prevalently used for production of microbial enzymes. Research by the companies is directed primarily to process development and improvement and to evaluation and application of products. Some of the effort concerns development of processes based on basic and applied research of the Department. Relatively little basic research is performed by the companies. Isolates are maintained and taxonomic work performed only in the area of interest.

Biological pesticides and related products are made by fermentation of cereal grains and grain byproducts. Research by the companies is directed principally towards process development and improvement and testing of products. A substantial part of the effort in this field

concerns processes based on results of research conducted in the Department. A relatively small amount of basic research is conducted.

Animal feed supplements containing vitamins, antibiotics, enzymes, and other microbial products are manufactured largely by fermentation processes based on cereal grains and grain byproducts. A considerable research effort is devoted by industry to improvement of existing processes, to the development of new products and processes, and to evaluation of products. Several companies are engaged in discovery and development of microbial products containing so-called "unidentified growth factors." Some basic research is performed. Although quantities of human foods are prepared by fermentation processes, there is very little activity in regard to fermented foods derived from cereal grains.

Except for cooperative work that may result from preliminary evaluation of products and processes developed by the Department, the specific nature of the research in these fields and the results are kept confidential or patented by the companies. Estimated annual expenditures for research in these areas are equivalent to approximately 30 professional man-years in basic research, 90 professional man-years in applied and developmental research on industrial chemicals, 35 professional man-years in applied and developmental research on biological pesticides, less than 5 professional man-years in applied and developmental research on fermented foods from cereal grains, and 70 professional man-years in applied and developmental research on feed supplements.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Basic Research on Fermentation Processes

1. ARS Culture Collection maintenance and service. As of January 1, 1962, a total of 9,983 organisms were in the permanent collection of pure authentic cultures. This represents an increase during the past two years of 1,100 cultures. Some 3,187 culture transfers were distributed to domestic institutions and 1,425 to foreign ones.

After several years of negotiation, an exchange of nine streptomycete strains was made with Dr. G. F. Gause, Academy of Medical Sciences, Moscow, Russia. Also by exchange, 6 mold cultures were obtained from Poland and 53 strains of bacteria from Czechoslovakia, including a number of strains from insects. To prevent loss or destruction of the more important ARS Culture Collection strains, duplicate cultures are being stored at Olustee, Florida. A total of 1,749 strains is now there.

A total of 314 yeast cultures have been received from the National Institute of Agronomic Research, Madrid, Spain, and the University of Allahabad, India, has sent a number of unusual Mucoraceous fungi.

2. Bacteria investigations. Taxonomic studies on actinomycetes under a cooperative agreement with the Society of American Bacteriologists (now known as American Society for Microbiology) have now been completed. During the past 3 years some 2,000 strains were categorized into groups using a new scheme. About 1,000 of these strains were characterized by straight to flexuous fruiting bodies and were selected for more intensive study. Partial results were obtained on about two-thirds of these strains. Data collected on 129 strains were analyzed by ARS Biometrical Services to determine the merits of classification based on correlations among morphology of fruiting bodies, color of aerial mycelia, selected physiological tests, and nature of antibiotics produced. Certain patterns of correlation appear to exist, but more definitive information on antibiotic production is needed.

The first part of an investigation of a taxonomic group of streptomycetes, comprising about 50 antibiotic-producing strains, has been completed by determination of customary characteristics and antibiotic spectra.

Research on Pseudomonas is in abeyance because of assignment of the limited number of available qualified personnel to more urgent work. Some 27 strains of Pseudomonas, including a new species, have been received for future study. A group of 26 strains has been sent to Louisville University for use in a cooperative serological study of taxonomic relationships.

3. Yeast investigations. Following the discovery of sexual agglutination of certain genera of yeasts, described in the 1960 report, work was initiated that has as its objective a comprehensive study of this unusual phenomenon as a basis for developing new yeasts and new processes for fermentative conversion of cereal grains into new products. Blocking of sporulation is found in siblings of almost all strains of diploid species of Hansenula that possess sexual agglutination but blocking is absent in siblings that lack sexual agglutination. The function of blocking therefore was investigated. Siblings obtained from a strain isolated in Illinois were sexually agglutinative when mated among themselves, and the bisexuals they formed on mating were sterile. The same was true for siblings from a strain from Japan, but when mating types from the Illinois strain were mated with those of the Japanese strain, the resulting bisexuals were capable of producing sexual spores. Similar results were obtained with other strains from less widely separated geographic areas. Increasing degrees of inbreeding between the Illinois strain and one from Louisiana have shown increasing strength of blocking in the crosses. The discovery of spore blocking in Hansenula may enable the

production of stable, inbred strains incapable of sexual reproduction, that may have value for fermentative production of new chemicals or for use in assaying vitamins and antibiotics. A primitive form of sexual agglutination was found in two genera of related yeasts, Hansenula and Pichia. The process is a mechanical one in which the yeast cells produce tubes or filaments that connect cells directly together. Study has begun on a new family of yeasts believed to be predecessors of the important Basidiomycete and Ascomycete classes of fungi. The new family differs from all other fungi in producing no sexual spores, although strong sexual reactions are observed.

4. Mold investigations. Studies were made of the sexual behavior of Absidia species. One species, A. cylindrospora, exhibited a hitherto unknown type of mating reaction. A "+" mating type reacted with some "-" types but not all. No explanation of this behavior is evident unless some of the more complex sexual situations associated with higher fungi are present. This work has also resulted in discovery of the sexual stage in two species of Absidia and in discovery of a new variety of A. blakesleeana. Taxonomic studies revealed a species, A. verticillata, that is parasitic on other Mucorales. Of 30 selected Mucorales, 10 species in 6 genera proved to be hosts of the parasite. So far as is known, this is the only parasitic Absidia.

Success was achieved in germinating spores of three strains of Rhopalomyces sp. at high pH's on a special medium. The first pure cultures in existence of this microorganism are, therefore, now available. It was shown that this fungus parasitizes and kills the eggs of certain nematodes but does not affect adults. Now that it can be grown in pure culture, its parasitic properties and potential value to agriculture can be studied.

Some 50 new cultures were added to the collection of fleshy fungi, making a total of about 450 since inception of the project. Yields of ramulosin, the seed germination inhibitor isolated from cultures of Pestalotia ramulosa, have been increased to nearly 16 percent based on glucose. Three species of Calvatia were found to yield an orange crystalline product. Preliminary characterization suggests a secondary or tertiary amine. Mouse tumor tests done at Battelle Memorial Institute in connection with the cancer testing program of the National Institutes of Health on 50 filtrates were negative, but 5 showed some promise in cytotoxicity tests at the University of Miami. Analysis of several promising filtrates showed that one contained mannitol and that three others contained polymeric materials as the chief non-glucose products. Analytical and cultural procedures for exploring fleshy fungi have been reexamined and modified for use in future work. Further study and reconsideration of results to date with 120 cultures showed that 26 percent had conversion characteristics warranting additional investigation.

5. Microbiological processes and products. Exploratory studies were made to discover new microorganisms that would give increased yields of hydroxyl-containing products by fermentation of a medium containing unsaturated long chain fatty acids. Optimum results were obtained with a Pseudomonas species isolated from oily residues found in a soybean oil processing plant. With this organism, oleic acid was converted to 10-hydroxystearic acid in yields of 14 percent with a medium containing 1 percent of oleic acid. The identity of the product was established by chemical analysis, determination of physical properties, and study of its behavior in a mass spectrometer. These results demonstrate production of a potentially useful industrial product from oleic acid by a highly specific microbial transformation. However, yields were too low to give the process practical significance, and it appeared unlikely that much higher yields could be realized. Furthermore, since the fermentation was aerobic, it could not be used satisfactorily with polyunsaturated fatty acids because of the ease with which they undergo autoxidation. Work on hydroxylation has been completed. Similar work has been initiated, however, on fermentative conversions of unsaturated fatty acids to amino derivatives. Selected yeast cells were incubated in a medium containing sodium fumarate and ammonium chloride. Chromatographic analysis of amination medium showed the presence of aspartic acid, thus demonstrating the ability of microorganisms to aminate the double bond of an organic acid. 4-Amino-hexanoic acid was synthesized, and its chromatographic R_f value and color reaction with ninhydrin were determined. Based on this information a screening procedure was devised whereby ability of organisms to aminate the model compound 3-hexenoic acid can be detected. Thirty organisms were screened with negative results. Further screening studies are in progress.

In the Pioneering Laboratory for Microbiological Chemistry studies on the enzymatic pathway by which pentoses are oxidized in Pseudomonas fragi revealed that while intermediates are the same for each pentose studied, the enzymes involved are different. The particulate aldose dehydrogenase, a constitutive enzyme, was unusual in that it oxidized glucose to glucono- γ -lactone whereas previous known enzymatic or chemical reactions yielded the δ -lactone. By use of immunological techniques, it was observed that in photosynthetic bacteria the photophosphorylation reaction could be interrupted by reagents capable of opening and blocking disulfide bonds. This observation resulted in discovery of an enzymatic, light-activated, disulfide reducing system in the bacterial particles. This system, first of its type to be found in photosynthetic particles, promises to be useful for studying relationships between particle structure and catalytic activity. Preliminary results of recently initiated studies of the mechanisms involved in yeast agglutination revealed that disulfide splitting reagents inactivated the agglutinating ability of one strain of yeast, whereas acid, base, and hydrogen bond-breaking reagents were more effective with a second strain. Chemical structures have been determined

for several metabolites. These include tetraacetylphytosphingosine (an extracellular lipid), ramulosin (an inhibitor for seed and fungus spore germination), and fonsecin (a yellow pigment).

At the University of Helsinki, Finland, nucleotides from radioactive yeast (Torulopsis utilis) were isolated and fractionated by chromatography on Dowex-1. The fractions were further separated by means of two-dimensional radio paper chromatograms and other techniques, enabling identification of the following compounds or mixtures: diphosphopyridine nucleotide; adenosine monophosphate; cytidine monophosphate; guanosine monophosphate + cytidine diphosphate; uridine monophosphate + inosine monophosphate + adenosine diphosphate; uridine diphosphate; cytidine triphosphate; adenosine triphosphate; guanosine triphosphate; uridine triphosphate; cytidine diphosphate - sugar; guanosine diphosphate - mannose; triphosphopyridine nucleotide.

With the possible exception of a substance tentatively identified as cytidylmonophosphoethanolamine, no new compounds were discovered. However, the following compounds identified have not been previously found in yeast: cytidyldiphosphocholine, cytidyldiphosphoglycerol, and cytidyldiphosphoethanolamine. It is hoped ultimately to apply the knowledge gained in this research to the analysis of microbial systems producing polysaccharide gums, phospholipids and other products having potential for industrial use.

Research at the University of Milan, Italy, on fermentation of glucose to 5-ketogluconic acid has disclosed that the oxidative and decarboxylative functions of Acetobacter cells can be separated in cell-free extracts and independently characterized. Results of this work may disclose means of controlling their respective enzymic activities and, in turn, lead to more effective fermentations.

B. Industrial Chemicals

1. Microbial polysaccharides. Work has been completed on the team project on microbial polysaccharides.

Polymer B-1459. This polysaccharide is now being produced in the pilot plant by three industrial companies and marketed by one of them. To achieve maximum utilization of B-1459, its price should be as low as possible. Consideration has been given therefore to improvement of the process and to possibilities of use of partially purified fermentation liquors, thus avoiding isolation of purified solid polysaccharide. Studies on process improvement involved investigation of a new method for precipitation of polymer and development of a less costly fermentation medium. It was discovered that a commercially available quaternary ammonium salt would precipitate the polymer. A successful process based on this reaction was devised. It permits recovery and recycling of the quaternary salt and eliminates the

relatively expensive methanol precipitation procedure. It was also shown that products, which, although impure, should be useful in applications such as oil-well drilling muds and flooding agents for secondary petroleum recovery, can be obtained by drum and spray drying of fermentation broths. Revised cost estimates show that selling prices of various industrial grades of drum- and spray-dried polymers would range from 50 to 71 cents per pound. Viscosities of solutions of these impure products are equivalent, on the basis of actual polymer content, to those of solutions of methanol-precipitated polymer. For solutions of equal viscosity, those from the impure products would cost 60 to 70 percent less than those from methanol-precipitated polymer. Structural studies have revealed the presence of pyruvic acid in polysaccharide B-1459 as well as in several other Xanthomonas polysaccharides. It is possible that the presence of this unique constituent may contribute to the unusual viscosity stability of B-1459 to heat and inorganic salts.

Polymer B-1973. This product was successfully produced in the pilot plant by methanol precipitation in yields of 40 percent, and 5 pounds was prepared for industrial evaluation. It can also be recovered easily from the fermentation broth by precipitation with a quaternary ammonium salt, but the quaternary salt can not be completely removed from the complex by washing. Viscosity measurements indicated unusual response to salts. Addition of 1 percent of calcium or sodium chloride to 1-percent solutions of B-1973 doubled the original viscosity, but there was only a slight decrease in viscosity when salt concentration was increased to 25 percent. Addition of 0.05-0.50 percent of aluminum sulfate to a 1-percent polymer solution caused gelation, whereas higher concentrations decreased viscosity to less than that of the original. The polymer contains glucose, galactose, and mannuronic acid (as K salt) in equimolar ratios and 25 percent by weight of acyl (as acetyl), indicating that polymer units may be triacetates. Three potentially useful forms of the polymer exist: native, autoclaved native and deacetylated. Each has individual properties of interest; e.g., autoclaved native polymer forms unsupported films of good tensile strength and excellent flexibility even when unplasticized.

Polymer Y-1401. Composition has been established as mannose:xylose:glucuronic acid (as potassium salt):acetyl in the ratio of 4:1:1:1.5. α -Linkages are indicated. Yields were about 40 percent in 20-liter fermentors and 16.5 percent in initial large pilot-plant runs. Although the properties of this polysaccharide are interesting, they are not as unusual as those of B-1459. For this reason further developmental work will be kept in abeyance pending evaluation of available sample material by industry.

Polymers B-2171 and B-1828 did not reveal properties sufficiently different from those of other polysaccharides to justify detailed investigation and developmental research.

Phosphomannans. Primitive yeasts of the genus Hansenula and related genera elaborate a whole series of extracellular phosphomannans when grown on a medium containing glucose as a carbon source. For 30 strains from 10 species studied, phosphomannans with molar ratio of mannose:phosphate varied from 2.5:1 to 27.5:1; the more primitive yeasts produce the more highly phosphorylated gums while the more highly evolved yeasts in phylogenetic lines yield gums with less phosphorylation. Mild acid hydrolysis of phosphomannans splits the cross-linking phosphate bonds yielding poly-mannosidic-6-phosphomonoesters. These relatively nonviscous polymers are acid-stable and act as dispersing agents, thus offering industrial potential.

Phosphomannan Y-2448 contains phosphorus:potassium:mannose in the molar ratio of 1:1:5. It is made up of chains of about 100,000 molecular weight and has a light-scattering molecular weight of about 16 million. The chains are crosslinked by hemiacetal phosphate bonds that are acid labile.

The structure of Y-1842 phosphomannan can now be described with considerable certainty as an oligosaccharide phosphoryl polydiester in which every fifth disaccharide unit contains an appended α -mannosyl residue. This structure can be explained by a simple, plausible scheme of biogenesis based on guanosinediphosphate mannose as the sole precursor. The mechanism would be applicable to all other phosphomannans.

Over 150 samples of phosphomannan Y-2448 have been distributed, and nearly 200 requests for information on phosphomonoesters have been received.

To encourage use of cereal grains as substrates for fermentative production of industrial chemical and other products, inexpensive media based on grain are needed. Preliminary cost studies indicated that enzymatically hydrolyzed corn should yield a medium containing fermentable glucose at a cost one-half that of commercial corn sugar. Such a medium, it is believed, might prove to be competitive with molasses. Research was, therefore, initiated to investigate this possibility. Initial experiments have revealed conditions permitting 95-percent conversion of starch to glucose.

2. Fermentative products from flour and gluten. Investigations on production of polyglutamic acid and on deamidation of wheat gluten have been completed. The polymeric product obtained by liquefaction of wheat gluten with strains of Bacillus subtilis was found to be a mixture of polyglutamic acid and carbohydrate material that may have come from starch in the crude wheat gluten used. Methods were developed for isolation and purification of the polyglutamic acid. With fermentation times of 24 to 48 hours, the yield of polymer was equivalent to 33 to 42 percent of the glutamic acid in gluten. The polymer

contained 60-95 percent of D-glutamic acid, the remainder presumably being the L-isomer. In the pilot plant, polyglutamic acid was successfully produced in 20-liter fermentors in yields representing 15-17 percent conversion of glutamic to polyglutamic acid. Yields were low because of excessive foaming. For economic reasons, fermentative production of polyglutamic acid does not appear attractive at the present time. However, predicted excess industrial capacity for fermentative production of glutamic acid may require industry to seek new outlets for this acid. Hence industrial interest in conversion of glutamic acid to polyglutamic acid could develop.

Although research on deamidation did not result in products potentially useful to industry, good sources of proteolytic enzymes were developed. The proteolytic enzyme of B. subtilis NRRL B-2612 was isolated in highly purified condition. It was found that the viscosity of gluten could be effectively and controllably reduced by enzyme action. The products still had considerable molecular size and were quite uniform. These results suggest possibilities for enzymatic modification of wheat flour to obtain paper coatings, adhesives and related products. Research has been undertaken to explore these possibilities.

3. Fermentation acids. In the production of vital gluten from wheat by the batter process, a byproduct is a slurry (starch milk) containing starch, soluble sugars, and soluble nitrogen compounds. This starch milk may be used as a source of starch or fermented to beverage alcohol. It would be economically more advantageous, however, to convert starch milk to a valuable industrial product such as citric acid. Initial work showed that the starch must be hydrolyzed prior to sterilization in order to avoid gelatinization. A liquefaction procedure was developed for this purpose based on use of a heat stable α -amylase enzyme. Treatment of starch milk with the enzyme for 30 minutes at 78° C. thinned out the slurry completely, and the product remained liquid during pressure sterilization. Yields of 90 percent of theory (based on starch consumed) were obtained when the manganese content was increased to 20 p.p.m., the value in the wheatberry.

The role of added methanol in fermentation of starch milk with a specific strain of Aspergillus niger has been investigated. During the growth period of the mycelium, methanol is metabolized. After the mycelium is fully developed, no methanol is utilized, indicating that it does not enter into the formation of citric acid. If no methanol is added to the medium, this strain gives only a 10-percent weight yield. The effects of added manganese and methanol make fermentative conversion of starch milk to citric acid economically and technically feasible. Present estimates indicate that carbohydrates in the starch

milk of the batter process can be made available at about the same cost as sugars in high-test molasses. The strain ferments the starch milk without the formation of oxalic or gluconic acid. Currently citric acid sells for 28 cents per pound and oxalic acid is 18 cents per pound.

Work on development of a process for recovery of α -ketoglutaric acid from fermentation liquors, which was effected at Augustana Research Foundation, Rock Island, Illinois, has been completed. A successful process was devised that should be readily adaptable for industrial use. Approximately 80 percent of α -ketoglutaric acid present in the fermentation liquor can be recovered as calcium salt approaching 100-percent purity. Essential steps in the process are extraction of α -ketoglutaric acid with cyclohexanone and precipitation of the calcium salt. Even higher yields would be expected in an actual industrial application of the process where continuous extraction and multiple crystallization would undoubtedly be utilized.

C. Biological Pesticides

1. Biological insecticides for Japanese beetle. A significant advance was made in research, conducted with the cooperation of the Entomology Research Division and the Plant Pest Control Division, on development of large-scale production of "milky disease" spores for controlling Japanese beetle. The viability of cells of Bacillus popilliae has been improved substantially so that cells produced in liquid media remain alive for a period of time that may be sufficient to allow sporulation under favorable conditions. The principal change in procedure that permitted improvement in viability was increase of buffer (K_2HPO_4) to 0.6 percent.

A semisynthetic liquid culture medium was developed for the propagation of B. popilliae in which a number of cells show early stages of spore development. Sporelike forms have been obtained repeatedly when B. popilliae is grown on the surface of a solid medium containing sodium acetate but no glucose. No spore forms were obtained if lactate or glucose were present.

Studies on grub blood and live grubs are vital to this work because grub blood is, so far, the only liquid medium in which sporulation of milky disease organisms occurs. The amino acid composition of hemolymph from diseased Japanese beetle larvae was found to contain more lysine, glutamic acid and ornithine and less arginine, proline, alanine, serine and tyrosine than does hemolymph from healthy larvae. Glutamine is apparently hydrolyzed in deceased larvae. Hemolymph of normal grubs was about 33 percent saturated with oxygen in respect to air, whereas in infected grubs this value ranged from 5 percent (spores present) to 15 percent (only vegetative cells present). Through the

cooperation of General Dynamics Corporation, quantitative elemental analysis of normal grub hemolymph has been obtained.

At Michigan State University, information on the metabolic pathway for glucose in B. popilliae is being developed. One preliminary result of interest is that low oxygen supply may result in production of three times more lactate than acetate from glucose, while with high oxygen supply no lactate is produced.

2. Insect attractants. In cooperation with Entomology Control Division field stations, a total of 520 cultures, representing 149 species of yeasts, 63 species of bacteria, 126 species of molds, 47 species of actinomycetes and 135 cultures from 5 groups of fleshy fungi, were grown on grain-based media and tested as insect attractants either as whole cultures or as centrifuged supernatants. The fermenting whole culture product of the yeast Candida utilis, Y-900, appears to be the most promising. Lures prepared from this product were four times as effective as the standard lures for attracting Mexican fruit flies.

3. Plant antibiotics. Screening of 1,000 actinomycete isolates has been completed. About one-fourth of them produced antibiotics of interest and were further studied to increase yields. During the last two years of these studies, Crops Research Division conducted greenhouse tests on 184 fractions and filtrates for effectiveness against rust, anthracnose, downy mildew, bacterial blight, and mosaic of beans. Forty-three of these samples gave positive results against one or more of the five diseases. Comparative chromatography eliminated a number of isolates that produced known antibiotics. Appraisal of the overall results has reduced the number of choice strains to 20 for more intensive study.

The F-17 antibiotic mixture elaborated by Streptomyces cinnamomeus forma azacoluta Pridham et al., NRRL B-1699, has been resolved into the following:

F-17-A: Possibly a mixture of two or three antibiotics of unknown structure having antibacterial activity.

F-17-B: Duramycin, a polypeptide active against gram-positive rods and some yeasts and molds but ineffective against bean rust.

F-17-C: An antifungal heptaene complex having virtually no activity against bacteria, streptomycetes, or bean rust.

Antibean-rust factor: Highly active fractions were isolated, but the active agent was not characterized as a pure compound. Recent evidence suggests that the antirust factor(s) and the antibacterial factor(s) of F-17-A may be the same.

This work, which completes studies on the F-17 mixture, resulted indirectly in the discovery that phleomycin, an antibiotic discovered in Japan, was active against bean rust at a level of 0.17 p.p.m.

Work was begun on a screening program designed to find antibiotics effective against a selected group of plant fungi, specifically Alternaria solani, Fusarium oxysporum f. lycopersici and Mucor ramannianus. Since these test organisms can be cultured in the laboratory, more rapid and effective screening is possible than when greenhouse tests provide the only method of in vivo testing. Only materials showing the greatest activity against the test organisms will be submitted to Crops Research Division for further testing. Since inception of this work 358 streptomycete strains have been screened, of which 48 showed potential nonpolyenic antifungal activity. Further screening for stability reduced this number to 15 promising strains.

D. Feed and Food Products

1. Microbial carotenoids. Studies are being completed on the production of β -carotene by fermentation of cereal-based media. By use of new, more efficient strains of the organism Blakeslea trispora and addition of both a nonionic detergent and a specially purified kerosene fraction to the medium, yields of β -carotene were increased to 90 to 100 mg. per 100 ml. of medium. Other ingredients of the medium are hydrolyzed corn and soybean meal, animal fat, β -ionone, and thiamine hydrochloride. Replacement of hydrolyzed corn and soybean meal by whole corn and inexpensive, commercially available cottonseed embryos gave yields of 135 mg. per 100 ml. of medium. Also, replacement of β -ionone with citrus pulp gave yields of 102-109 mg. per 100 ml. Even though only 0.1 percent of β -ionone was used in the medium, this chemical is so expensive that its replacement by citrus pulp results in reduction of the estimated "cost to make" of the product from \$42 to \$32 per kilogram. Whereas previous yields indicated a process of marginal economics, current yields should provide the basis for an attractive industrial process. Six industrial organizations that are evaluating the process reported that they were able to equal or exceed the stated yields of product.

Further studies have shown that a variety of citrus products, including dry citrus meal and citrus essential oils, can replace β -ionone. The active principle of dried citrus peel that permits its substitution for β -ionone in fermentative carotene production can be eluted in a water-soluble fraction. The active precursor in grapefruit and tangerine oils was identified as limonene. The compounds 4-keto- β -ionone, 4-hydroxy- β -ionone and β , β -dimethylacrylic acid have been synthesized for study as precursors in xanthophyll production.

2. Vitamin B₁₃. A method for extracting large batches of distillers' dried solubles (DDS) for vitamin B₁₃ activity yielded a preparation having animal growth activity. Mevalonic acid and orotic acid, both present in DDS, seemingly have been eliminated as contributing to B₁₃ activity. Studies on the characterization of the vitamin showed that a fraction of "B⁺₁₃ concentrate," purified by high vacuum distillation, as well as the original extract, yielded upon acid hydrolysis a product containing about 14 amino acids. This research is conducted by the "Giuliana Ronzoni" Scientific Institute of Chemistry and Biochemistry, Milan, Italy.

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WHEAT AND BARLEY--

FOOD AND FEED PRODUCTS AND PROCESSING

Western Utilization Research and Development Division, ARS

Problem. In recent years huge stockpiles of wheat and barley have accumulated, exerting a severe depressing effect on the agricultural economy through restricted grower incomes and expensive government control programs. The most promising solution to this critical problem lies in greatly expanded exports to meet the urgent food needs of large segments of the world's population and to secure an increased share of prevailing and future dollar markets for these grains. Knowledge and skills do not now exist to reach these goals. Ways must be found to adapt U.S. winter wheats and flours to the specific use requirements in Western Europe, currently representing a large potential dollar market. New food products from wheat must be created to fit specific needs and preferences of individual countries throughout the world. Simple inexpensive methods must be devised for use in developing countries to process U.S. wheats into products appropriate for their socio-economic structures. Greatly expanded scientific knowledge of the composition and processing properties of wheat and barley is essential to accomplish these important objectives. More complete knowledge of the chemical and physical properties of both the major and minor constituents of the grains, and of the changes that occur among them during processing, is needed to point the way to the new food and feed products and to new processing technologies. A thorough exploration must also be made of the inherent versatility of these grains as food and feed substances to achieve the utmost of their wide use potentialities.

USDA PROGRAM

A broad program of basic and applied research on wheat and barley is being conducted by the Western Utilization Research and Development Division at Albany, California; under contract at Pullman, Washington, Cambridge, Massachusetts, Lafayette, Indiana, Corvallis, Oregon, and Ames, Iowa; and under P.L. 480 research grants in England, France, Poland, Italy, and Israel.

Basic studies are concerned with characterizing the soluble proteins (albumins and globulins), gluten proteins, lipoproteins and lipids in wheat and flour, and identifying interactions in and between these substances; and characterizing the biologically-active compounds present in bran and germ. Different varieties and classes of wheat are being studied to determine intrinsic differences between the relatively scarce high quality bread-baking wheats and those surplus wheats which require chemical treatments to make possible their use for bread production. Applied research is being conducted on new

and improved food and feed products and processes, with emphasis on the development of products to help fill the food deficit in overseas countries.

The Federal program of research in this area totals 28.0 professional man-years.^{1/} Of this number 17.1 are assigned to chemical composition and physical properties; 10.0 to new and improved food products; ^{2/} 0.6 to new and improved feeds; and 0.3 to new and improved feed processing technology. In addition, the Division sponsors 28.8 professional man-years of research under P.L. 480 including 22.8 on basic studies and 6.0 on applications of research findings.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Stations in the North Central and Western areas in 1961, reported 6.6 professional man-years divided among subheadings as follows: Chemical composition and physical properties 5.2, new and improved foods and food and feed processing technology 1.4. Basic studies underway are concerned with the compositional, biochemical and physiological factors which influence technological properties of wheat. These studies should yield information on the basic differences between the hard, soft and durum wheats which are under investigation. Applied research involves investigation of the causes and effects of moisture translocation in canned baked goods, development of non-staling bread-like products, development of mixing specifications, and milling studies.

Industry and other organizations including milling companies, baking companies, grower organizations, and allied industries such as suppliers, conduct research programs that are predominately concerned with specific applications to individual corporate problems. The predominant scientific activity in industry organizations is concerned with quality control of products and raw materials, with a

^{1/} In addition, a program equivalent to 7.0 professional man-years, including 3.1 for improvement of the wheat bulgur wafer for civil defense food stockpiles and development of food adjuncts to supplement the use of wheat bulgur wafers under conditions of emergency use and 3.9, by contract, for a study of factors affecting stability of wheat bulgur wafers was initiated with funds transferred from the Office of Civil Defense, Department of Defense.

^{2/} Including non-recurring funds equivalent to 3.9 professional man-years from the Administrator's F.Y. 1962 contingency appropriation, used to initiate a contract project on development of protein-rich, water-dispersible export wheat food products; and industry support by way of salaries provided by The Farmers Co-Operative Commission Company for two employees developing new wheat food products.

somewhat lesser emphasis on product and process development and improvement. Virtually all of the research information obtained is confidential or protected by patents. Published information most often concerns laboratory procedures or fundamental findings. All of the companies keep themselves well informed on the progress of research conducted in government laboratories, but their greatest demand is for fundamental information. Grower organizations who are expending modest sums to support research work on wheat, in contrast to commercial companies, seek more information on new and improved products from government laboratories. Estimated annual expenditures in this area by industry and other organizations are equivalent to 160 to 200 professional man-years.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Chemical Composition and Physical Properties

1. Soluble Proteins and Sulfhydryl Groups in Flours. High-speed, and continuous dough-mixing equipment now in use by modern bakeries demands unusually high-grade wheat flours. Only 10 to 30% of our normal wheat crop is regarded by the industry as being suitable for use in this machinery. Why some flours will withstand severe mixing and others will not, is not known. Results of basic research on wheat proteins are beginning to offer some explanation for this difference.

In research conducted during the past year, the presence in flours of a lipoxidase enzyme capable of oxidizing sulfhydryl groups was demonstrated in model experiments using a low-grade (5th break) flour shaken in a slurry with added glutathione and safflower oil, the latter being the substrate for the enzyme. Heating and/or deproteinization of the flour greatly reduced the extent of oxidation of sulfhydryl groups (those in glutathione plus those in flour) during a fixed reaction period. Substitution of methylolinoleate for the safflower oil more than doubled the rate of oxidation of the sulfhydryl groups so that 82% of these had disappeared after two hours of shaking at room temperature.

Comparison of gel-electrophoresis patterns of water-soluble proteins from a Rio variety flour and a high-protein air-classified fraction from it, showed no qualitative and only minor quantitative differences. This contrasts with some qualitative differences observed among patterns from Rio, Brevor, Burt, and Omar (a club wheat) variety flours.

The results obtained in these studies, provide guidance to efforts to produce and provide flour blends of optimum quality for specific uses. They suggest that air-classification milling, which up to the present time has been applied largely to intermediate type wheats,

may have important applications in the Pacific Northwest. The currently reported work also provides means for obtaining valuable materials for basic research on correlation of chemical and physical composition of wheat with baking properties of flours derived from them. (Research in this field relating to new and improved food products is reported below.)

Contract studies underway at Washington State University are aimed at developing rapid and simplified methods for determining individual flour proteins. A variety of electrophoretic and paper chromatographic techniques are being investigated with respect to suitability for analytical separations of proteins in flour extracts for the purpose of quantitative estimation of individual components. Particularly promising results were obtained with disc electrophoresis in polyacrylamide gels. Densitometry of stained protein bands in gels appears entirely feasible. Present results indicate that variations in dye-binding capacity by different components can be determined by accessory use of the optical system of the Perkin-Elmer free boundary electrophoresis apparatus for determination of protein concentrates in unstained gels. Results can then be compared with values obtained by routine methods for stained proteins. Extraction of soluble proteins from flour is improved by prior removal of lipids with water-saturated butanol. Procedures for extraction and separation of albumin and globulin as groups require additional refinement to reduce cross-contamination.

2. Relation of Sulfhydryl to Enzymes in Wheat. Basic studies on the relation of sulfhydryl groups to the amylolytic and proteolytic enzymes in wheat, flour and malted wheat are being carried out under P.L. 480 at the University of Poznan, Poznan, Poland. Some of the accomplishments of particular value include observation of rapid loss of sulfhydryl from ground whole wheat; elucidation of precautions required to get reproducible results in sulfhydryl determinations; improvement in precision of proteolytic activity assay; and demonstration of a definite, but limited reduction of proteolytic activity in the presence of sulfhydryl blocking reagents.

3. Immunochemical Analysis of Wheat and Barley Proteins. Pioneering research in this unexplored field is being carried out under P.L. 480 at Pasteur Institute in Paris. The objective of these investigations is to develop sensitive and precise immunochemical methods for establishing correlations between the presence or amount of different wheat or barley proteins and derived products. Each protein preparation is injected into several rabbits, and the serum of these rabbits is then pooled and concentrated for electrophoretic studies. Excellent progress is being made in a difficult unexplored field.

4. Flour Lipoproteins. Research on lipoproteins is aimed on determining the fundamental chemical and physico-chemical basis for the

behavior of flour doughs and batters during mixing, fermentation, machining, and baking. The lipoproteins are important in various ways and evidence indicates they may play a dominant role in dough rheology.

The decreased solubility observed for gluten in acetic acid or aluminum lactate buffer which occurs after extraction of gluten lipids with wet butyl alcohol followed by acetone was found also to occur if the acetone wash is omitted. Variations in exposure time to the butyl alcohol and in the state of subdivision of the gluten particles, had little, if any, effect. The portion of gluten made insoluble in acetic acid can be dissolved in strong formic acid. Upon electrophoresis in aluminum lactate, the redissolved material appears to consist almost entirely of glutenin and the alpha components of gliadin.

Low- and high-protein fractions obtained by air-classification of a commercial straight grade flour from club wheat, had lower (1.4%) and higher (4.4%) total lipids, respectively, than the original flour (1.8%). On a unit protein basis, however, the percentage of lipids fell as the protein content increased. Both flour fractions had higher percentages of complex lipids and lower nitrogen to phosphorus ratios in their total lipids than the original flour. Somewhat more galactolipid plus lipoprotein was found in the complex lipid fraction of the low-protein flour fraction than in that of the high-protein fraction. Such information is useful in characterization of the wheat proteins as they occur naturally in the kernel. One form adheres tightly to starch granules and is concentrated in low protein fractions. The other occurs in interstices between granules and becomes concentrated in high protein fractions during air classification. Both forms appear to be intimately associated with lipids as they occur in the kernel.

In studies on hard red spring (HRS) wheat, it was found that lipids in a gluten washed from the flour amounted to about 9% dry weight of the gluten. Separation into classes yielded slightly more compound than simple lipids, with the phosphorus and most of the nitrogen in the compound lipids. These distributions are like those for the flour from which the gluten was prepared and the air-classified club wheat flours mentioned above. The nitrogen to phosphorus ratio was lower in the gluten than in the HRS flour lipids. Fractionation of compound lipids from the gluten and from the high- and low-protein air-classified flours, all gave 6 to 7 separated fractions based on phosphorus content. As the protein content of the original sample increased lipid sugars measured as galactose, decreased. As their polarity increased the fractions of each lipid generally contained more phosphorus and nitrogen. Sugar contents of the fractions increased to a maximum at the third to fourth fraction, then fell to

low values in the final fractions. Ester content showed an inverse trend with lowest values in fractions three and four. This trend was less evident with gluten than with flour lipids.

It was found that considerable non-lipid material (sugars, amino acids, peptides) remains in flour lipids even when dissolved in dry petroleum ether, and appears to interfere with fractionations. Washing chloroform-alcohol solutions of lipids by diffusion into aqueous 0.02% calcium chloride (Folch procedure) has been found useful to remove non-lipids.

The Folch-washed lipids of two hard red spring wheat and two hard red winter wheat flours were separated into neutral and polar lipids. Percentages of the latter were slightly higher in hard red winter (HRW) than in HRS flour lipids. Fractionation of the four polar lipid mixtures on silica gel provided very similar general distribution of components in each case, with minor but perhaps important differences. Analytical evaluation of these differences is in progress.

In order to identify lipoprotein components of gluten separated by starch-gel electrophoresis, glutens and gluten fractions in aluminum lactate-urea solution were pre-stained with Sudan Black B. Only the glutenin fraction, which did not migrate into the starch gel, was stained.

These findings suggest that appreciable differences in the ratio of glycolipids to phospholipids occur among flour and gluten lipids depending upon the protein content of the original sample. Such differences in composition could be expected to affect baking or other performance characteristics.

5. Whole Wheat Lipids. Basic studies on the composition of the lipids of whole wheat have very recently been undertaken under P.L. 480 at the Ecole Nationale des Industries Agricoles et Alimentaires in Paris, France. These studies seek more precise and complete knowledge of these lipids and their reaction to processing treatments.

6. Wheat Endosperm Constituents. Fundamental research on the constituents of wheat endosperm is designed to show the location and activity of various protein and cell wall components in the endosperm. Inevitably this research will lead to a better understanding of the perplexing differences in physical properties of flours, doughs and batters from different wheats.

Soluble proteins were extracted from air-classified fractions of Rio (hard red winter) wheat flour. Dialyzed extracts were chromatographed using gradient elution. In all runs, there was a major fraction of

essentially unadsorbed material. Runs at higher pH's showed two major and two to three minor peaks from the gradient elution with no important differences between the flour as-milled, coarse residue, fine and intermediate fractions. At lower pH's there were definite differences between the chromatograms of the as-milled flour and those of the fine and intermediate fractions. A major peak present in the original flour was missing from the two fractions and there were lesser differences between the two fractions themselves.

Polyacrylamide gel electrophoresis allowed better resolution than starch gels at the same buffer conditions and avoided an anomaly which appears in the latter type of gel on the anode side. At least 15 electrophoretic components have been found in an aqueous extract (pH 6.0) of a hard red spring wheat flour. Ion exchange separation has been quite effective in fractionation of regular progression, in keeping with sequence of components off the column. Four or five components showing greatest migration toward the cathode were missing after fractionation; they appear to be contained in material passing unadsorbed through the ion-exchange column. Rechromatography has improved the separations, although none of the components have yet been obtained in completely homogeneous condition as determined by gel electrophoresis. The effect of a sulfhydryl blocking reagent (N-ethylmaleimide) on the electrophoretic pattern has been tested and no difference has been noted. Greater fluidity of the extracting mixture containing NEMI was quite evident in keeping with its normal action.

Electrophoretically pure preparations of single components have not yet been prepared in significant quantity, but substantial concentrations of major components are now available for amino acid analysis and tests of functionality. The electrophoretic anomaly or discontinuity appearing in starch gels but not in polyacrylamide gels appears to be due to a definite component which also is the highest in beta-amylase activity. This enzyme activity is eluted from columns over a fairly wide range, but with a definite peaking of activity. It is among the last components to be eluted from the cellulose ion-exchange columns, but is among the constituents moving most rapidly toward the anode during gel electrophoresis, in agreement with earlier observations using paper chromatography.

7. Wheat Germ Proteins. Public Law 480-supported research on the separation and characterization of the major protein and non-protein nitrogenous constituents of wheat germ is just getting underway at the University of Bologna, Bologna, Italy. Knowledge of the free amino acids, nucleic acids, phospholipids, and free amines in wheat germ will provide means of better utilization of wheat fractions for food supplementation and in mixed feeds.

8. Enzyme Action in Low Moisture Grain. Studies of enzyme actions in solid natural products, in relation particularly to water contents in the range occurring in cereal grains, are being carried out under P.L. 480 at the Institut National de la Recherche Agronomique in Paris. Major emphasis is being placed on cereal lipases, and studies will involve kinetic investigations of their activities on enzyme--synthetic substrate mixtures under various well-defined conditions of water vapor pressure, temperature and oxygen partial pressure.

9. Protein Interactions. Basic studies of the interactions among wheat proteins and the contributions of individual components to the properties of the natural protein systems were recently initiated. Preparation of working quantities of purified individual proteins, especially those of gluten, was commenced as a first step toward elucidation of specific interaction mechanisms. Empirical studies of relations between mixing, sulfhydryl groups, and solubility properties of the proteins initiated earlier were intensified.

Comparisons of the amounts of protein extracted from flours and freeze-dried doughs by acetic acid and aluminum lactate buffer demonstrated that the development of doughs by mixing alters the protein constituents in such a way as to increase the extractable protein. For example, 2/3 of the nitrogen of a spring wheat flour was extractable, but 85% could be obtained from the dough mixed to a maximum resistance in a farinograph recording dough mixer. The increase was shown to be at the expense of material which when the original flour is suspended in the dilute acetic acid or buffer, settles rapidly and appears to be highly hydrated.

The rate and extent of conversion to extractable protein in doughs mixed in a farinograph differed markedly among four flours. More vigorous mixing (mixograph recording dough mixer) converted more protein to an extractable form more rapidly than the farinograph. When salt was added to doughs, both the rate and extent of the changes were decreased. In doughs mixed in a nitrogen atmosphere, extractable protein initially increased more rapidly than in air but in 20 minutes (farinograph), the increases in air were larger. In each case the nature of the changes indicated that the conversion of protein to an extractable form was related to the changes in physical properties, as indicated by the recording dough-mixer curves.

A Montana hard red winter flour of very poor mixing stability gave the highest values so far observed for both flour and doughs. A Nebraska hard red winter flour of very good mixing stability gave the lowest. The largest change upon mixing, however, was found with a hard red spring flour.

The addition of a sulfhydryl-blocking reagent, N-ethyl maleimide (NEMI), consistently increased both the rate and extent of change in extractable protein. In general, with this substance present, the maximum increase occurred in 5 to 10 minutes mixing in the farinograph, versus 20 minutes or more in its absence. The maximum proportion of protein extracted was increased an average of 9% by addition of NEMI (from 84 to 93%). Insoluble proteins amounting to about 30% of total flour proteins have been concentrated by high-speed centrifuging of highly hydrated residues remaining after extraction of flour with 0.01 N acetic acid. At 20,000 X gravity, whole starch granules are sedimented out of the gel quite completely. The dried gel fraction contains about 25% protein; insoluble pentosans and starch degradation products undoubtedly are still present.

Results obtained in these studies suggest that the change in acid-extractable protein with mixing occurs more readily and more extensively with spring wheat flours than with winter wheat flours. An interesting lead to further studies is thus provided.

10. Wheat Flour Dough Rheology. Basic studies aimed at developing methods for applying rheological principles to the measurements of properties of wheat flour doughs have very recently been initiated under P.L. 480 in the Rheological Laboratory of the Israel Institute of Technology at Haifa. Early activity under this grant has consisted primarily of assembly and modification of equipment to conduct this research.

11. Gliadin and Gliadin Derivatives. An important part of the program to increase the industrial usage of wheat is the development of high-value food uses for the protein fractions. Work has been concluded during the past year on the development of new and broader food uses for gliadin and deamidized gliadin.

Initial experiments with gliadin and deamidized gliadin as stabilizers in the foam-mat drying of fruit juices produced results at least as good as other proteinaceous stabilizers which are preferred over monoglycerides for fruit juices such as orange and pineapple. Regular gliadin gave better results than the deamidized gliadin. In cooperative studies with a local beverage producer, gliadins were evaluated as a foam-producer and stabilizer. It was found that gliadins have good foaming power but also cause serious haze formation upon chilling and/or storage. The pepsin-hydrolyzed gliadin performed best but haze formation with all three types of gliadin was heavy. This defect has so far been found with all proteinaceous foam stabilizers yet investigated and probably results from reaction with tannin systems present in the beverage. The high amide nitrogen content of gliadins is probably responsible for its affinity for tannin substances; nylon (also high in amide nitrogen), for example, can be used to remove the tannins from these liquids.

A simplified laboratory procedure was worked out for deamidation of gliadin by direct treatment of precipitated gliadin with hydrochloric acid thus avoiding the dilutions to 5 to 10% solutions previously used. Gliadin phosphate was prepared by heating a mixture of dry gliadin, phosphoric acid and urea. Solubility properties of the phosphorylated gliadin appeared generally similar to those of partially deamidized gliadin.

In further studies designed to reduce costs of extraction, acetic acid was substituted for the aqueous alcohol (isopropyl) previously used. By partial neutralization most of the non-gliadin constituents were removed. Complete neutralization then precipitated the extracted gliadin and after washing with water the product contained as little carbohydrate and lipid as gliadins prepared by the earlier procedure. Thus far, foaming properties of the product both before and after deamidizing have been poor.

The glutenin residue after extraction of gliadin with acetic acid, was added to a commercial flour of mediocre bread-baking qualities. Mixing tolerance of doughs and loaf volumes were increased in contrast to the lack of effect of glutenin obtained by the isopropanol extraction procedure.

In studies aimed at simplifying the deamidation of gliadin, and decreasing the cost of preparing deamidized gliadin, it was shown that amide groups could also be removed by autoclaving a gliadin mass wet with acid which would increase the capacity of equipment for such a process. Sulfuric acid yielded products difficult to dissolve at neutral pH. Hydrochloric acid presents problems in corrosion of the autoclave and in "boiling over" of the gliadin mass during treatment. When phosphoric acid was used it was found that the gliadin phosphate was soluble at neutral pH, insoluble at pH 4 and had good foaming properties. It thus appeared to be simpler to use phosphoric acid to partially deamidize gliadin.

The foaming properties of gliadin extracted by acetic acid from gluten were only slightly improved by treatments with alcohol to remove residual lipids. Foaming properties of gliadin were improved by heating the gluten dispersion in acetic acid prior to separation of the gliadin; extraction with 95% ethyl alcohol then gave a product with foaming properties approaching those of gliadin isolated by the isopropyl alcohol method.

Ethyl and glycerol esters of gliadin were prepared by reaction of the alcohols with gliadin under anhydrous conditions in the presence of HCl. The esters had solubility properties similar to those of gliadin rather than deamidized gliadin; they were soluble at slightly acid pH, insoluble at neutral pH, and easily precipitated by salt. The ethyl ester gave poor foams; the glycerol ester gave

much better foams, but not as good as unmodified gliadin. Attempts to prepare a glucose-gliadin ester were not successful.

Beneficial effects on foaming properties of gliadin prepared from heated acetic acid dispersions of gluten appear to result from inactivation of proteolytic activity in the gluten. Viscosity decreases occurring in the absence of heating were accompanied by an increase in free amino groups but no increase in ammonia. Possible contaminating microorganisms were eliminated as a cause of the viscosity decreases. Heating in glass containers produced less denaturation of gluten protein than heating in stainless steel containers. Freeze-drying of reaction mixtures in the preparation of gluten and gliadin phosphates produced products as good or better than those obtained by the tedious and prolonged air-drying step formerly used.

Completion of these studies during the past year has allowed placing of added emphasis on other new products research.

12. Ultrasonic Study of Wheat Gluten. Studies of alterations in the chemical and physical properties of wheat gluten induced by ultrasonic vibrations are being carried out under P.L. 480 at the Institut National de la Recherche Agronomique in Paris. In early studies, it has been shown that ultrasonic treatment of gluten causes a decrease in solubility and viscosity, the latter being more pronounced than expected from solubility loss.

13. Phosphorus in Wheat Flour. Basic studies on the effects of phosphorus compounds on the baking qualities of wheat are being carried out under P.L. 480 at the Institut National de la Recherche Agronomique in Paris. Ten U.S. wheat samples, supplied by the Western Utilization Research and Development Division, are being evaluated. The amounts of phospholipids, phosphoproteins and phytin present in flours of known baking character are being determined.

14. Solubility of Gluten Proteins. Research on the solubility of wheat gluten proteins is being conducted under P.L. 480 at the Centre National de la Recherche Scientifique, in Montpellier, France. These studies are providing a better knowledge of the characteristics of gluten proteins in relation to their foaming and surface-active properties and of the means of increasing and decreasing the solubilization of these proteins in neutral solutions. It is expected that the results of these researches will provide the basis for developing means for improving the baking properties of flours, and will assist in the selection of wheats most suitable for specific uses.

15. Flavor Studies. Current trends indicate that abbreviated and continuous-mix baking processes with their marked economic advantages

will be used more and more by the baking industry. In these processes, pre-ferments must be used to provide a major part of the flavor derived from fermentation. The objective of this research is to gain information which will permit control of the pre-ferment process so as to make continuous process bread equal, or perhaps even superior to conventional, more expensive bread.

It was reported previously that twelve of the more than the twenty volatile organic acids produced in pre-ferments had been identified on the basis of retention volumes on a gas chromatographic column. During the past year six additional acids have been identified. This was accomplished by utilizing the emergence times of the free acids and of their ethyl esters (the acids are formic, lauric, myristic, crotonic, palmitic, and pyruvic).

Decreases of 5° and 10° C. in the temperature at which pre-ferments are prepared, had no effect on the total concentrations of acid and alcohol produced, but concentrations of both volatile and non-volatile carbonyl compounds declined proportionately to the temperature level used. The amounts of carbonyl compounds in pre-ferment show an interesting and consistent trend as fermentation proceeds. Volatile carbonyls increased steadily in amount throughout the six-hour reaction time. Non-volatile carbonyls, however, increased to a maximum within two to four hours and then decreased substantially. This effect is more prominent in pre-ferments made with relatively high sugar concentration. The non-volatile carbonyls appear to consist predominately of aldehydes and/or keto acids such as pyruvic acid, mentioned above.

In further work the separation of organic acids from pre-ferments prior to examination by gas chromatography has received attention. Extraction with methylene chloride gave reproducible results but it extracted different acids to different degrees, e.g., capric acid over 50%, acetic, lactic and pyruvic, about 5%. Little if any unsaturation was present in the extracted material. For quantitative analysis the procedure is not satisfactory. Therefore attention is now being given to the separation of acidic components from the pre-ferment mixtures by ion-exchange.

A method employing column chromatography for determination of total organic acids had been used earlier for analysis of pre-ferments. Its applicability to doughs was investigated. High recoveries of pyruvic, lactic, and acetic acid added to doughs was obtained.

Total organic acids were shown to increase moderately in concentration during the proofing (pan fermentation) of bread doughs made by a pre-ferment procedure; baking caused a larger increase. Total carbonyl compounds and total alcohols follow a similar course, except that the alcohols and volatile carbonyls drop to very low

levels as a result of baking. Among the volatile organic acids produced during fermentation, formic and alpha-methyl butanoic acids have now been clearly identified. This brings the total identified to 18. Gas chromatography of all acids present as their esters indicate the presence of at least 45 different components, although this total would probably include mono- as well as di-esters of dicarboxylic (non-volatile) acids present. Chemically leavened (glucono-delta-lactone plus bicarbonate) breads prepared with two- to four-fold concentrates of pre-ferments were at least equal, if not superior, in aroma to breads made by a typical laboratory sponge and dough method.

Aqueous isopropyl alcohol has been found to be a more effective solvent for carbonyl compounds in bread and bread doughs than water alone. Analyses of freshly mixed bread doughs, proofed doughs, and breads baked from the doughs have shown that the greater the starting concentrations of sugar and yeast in the pre-ferments used, the greater the concentrations of flavor substances in the dough and breads, as would be expected. Alcohol production during pan-proof is greater in doughs from richer pre-ferments, but production of total acids and total carbonyls is unaffected by starting levels of sugar and yeast. Preliminary taste panel tests indicate that breads made with the richer pre-ferments have more pronounced flavor and aroma, in keeping with the chemical results obtained and validating the practical importance of the work.

Preliminary baking experiments with chemically leavened doughs indicate that higher flavor-potency concentrates are obtained by freeze-concentration of pre-ferments containing yeast cells than from pre-ferment supernatants. Freeze-concentrated pre-ferments of either kind are more effective sources of fermentation flavor precursors for bread than any other experimental or commercial flavor-enhancing substances yet investigated. Fractionation of concentrates into neutral, acidic, and amino acid fractions has been undertaken to locate the source of the bread flavor precursors furnished by pre-ferments.

In studies of flavor as related to baking procedures, research was conducted to test the validity of the hypothesis that the formation of the brown coloration and attendant unique aromas and flavors in the crust of freshly baked bread is based on the reaction of amino compounds and reducing sugars (by way of the Maillard reaction, followed by the Amadori rearrangement). Crystalline products from glycine and glucose were prepared for model system study of the proposed reaction mechanisms. These products exhibited none of the fluorescence that eventually occurs as the browning reactions proceed, and which can be extracted from bread. It was noted that no fluorescence develops in an aqueous solution of the crystalline Amadori product during six weeks at room temperature or after one

hour at 100° C. Continued heating produced gradual browning and slowly-developing weak fluorescence. Increased fluorescence and crust coloration resulted from addition of 0.5% glycine (based on weight of flour used) to chemically leavened and yeast leavened bread. The fluorescence extractable from bread was almost completely confined to the crust. Based on these results it is presumed that all final Maillard reaction products arise from simple decomposition of Amadori compounds. The slowness of the development of fluorescence in browning during heating of the glycine-glucose Amadori product suggests a strong possibility that other reaction pathways are also important in the browning of amino acids and reducing sugar.

Seventeen free amino acids have been identified in fermented bread doughs ready for baking. In aggregate the free amino acids appear to account for the major part of the dialyzable amino-group-containing substances present in fermented doughs. Peptides of medium to low molecular weight appear to be absent or present in only very small amounts. In test tube experiments, browning induced between a number of amino acids present in doughs and several aldehydes produced during fermentation failed to produce any odor at all reminiscent of baked bread. Gliadin and gluten likewise failed to produce pleasant odors. Gas chromatograms obtained by very sensitive hydrogen-flame ionization equipment (aromagrams) from vapors of freshly baked bread crust and crumb differ markedly.

Quantitative studies have shown that up to 90% of the free amino groups available in fermented bread doughs for reaction with reducing carbonyl compounds in crust browning are furnished by insoluble proteins. Free amino acids and water-soluble proteins contribute less than 5% each. Ammonium ion concentrations also are low in magnitude. Pre-ferments used for the bread doughs also contain small amounts of free amino acids, ten of which were identified.

Improvements in gas chromatographic techniques have produced linear relationships between sample concentrations of organic acids and peak heights obtained with capillary chromatographic columns. Sample injection precision of ± 2 to 3% has now been obtained, and sensitivity of detection of individual compounds has been increased sufficiently to permit reliable detection of micromicrogram quantities of materials. Quantitative estimation of individual flavor compounds can now be undertaken with good confidence.

16. Pre-Ferments in Commercial Bread Baking Procedures. Contract research is underway at the Massachusetts Institute of Technology with the objective of determining the effect of modifying the composition of commercial-type pre-ferment doughs upon volatile flavor and aroma components in bread. Information gained in this work should aid in developing methods for producing commercial bread with enhanced flavor.

In early work, bread of suitably high quality and batch-to-batch uniformity was prepared by rigorous control of operating variables particularly a standardized time schedule. Flavor concentrates were prepared by vacuum distillation of volatiles from fresh bread into a series of suitable cold traps from which they were recovered by thawing under nitrogen, saturating with salt, and extracting with ethyl ether. The condensed liquid in the traps exhibited a typical fresh bread odor when thawed.

Analytical work has included the initiation of a survey of gas chromatographic column packings, conditions of operation, and methods for trapping and rechromatographing fractions. Initial results show that at least nine major components (including ethanol, acetone, diacetyl and crotonaldehyde) are detectable using column chromatography. Standardization and stabilization of the organoleptic taste panel methods has been accomplished. Triangle tests were selected as being most suitable and were used to show that 500 p.p.m. of L-leucine added to doughs produced a significant change in the flavor and aroma of the resulting bread. Quantities of flavor and aroma material and chromatograms (thermal conductivity detectors) for the recovered material were satisfactorily duplicated in separate extraction trials on different lots of fresh bread. The effect of addition of six individual amino acids, gliadin, casein, lactalbumin, maltose, and lactose to doughs has been evaluated organoleptically in triangle tests on bread crust and bread crumb. No difference was found between the effects of L-isomers or DL-mixtures of amino acids. A number of significant differences in odor or taste of crust or crumb resulted from the formula additions, but in most cases the control bread was preferred by the taste panel. The notable exception was proline. The odor of crumb and the odor and taste of crust of bread containing added proline were preferred by the panel over controls. Bread containing added proline was therefore selected as the subject for quantitative chemical examination of flavor and aroma components. Of the 16 compounds detected in flavor isolates, eight are major components, and seven of these have been rigorously identified. The remaining compounds are minor in amount, but tentative identity has been assigned to five. Of the carbonyl compounds present in the concentrates, acetoin and furfural are much more prominent than any others. Alcohols of detectable and measurable quantities include ethanol, propanol, isopropanol, and isobutanol. The lesser components present in flavor isolates appear to occur in quantities of the order of 3 to 6 parts per million.

B. New and Improved Food Products

1. Bulgur, the Parboiled Wheat Food. The development of canned whole-grain ready-to-eat bulgur products especially suited for the domestic market as a convenience food, but also for possible use in

the export trade has been reported previously. In the past year, there has been considerable outside interest in this new wheat food product, including a market test sponsored by a Midwestern State wheat commission. Research has continued towards enhancing the convenience features of the product.

A sample of hard red winter wheat from the intermountain region was found to take up water much more rapidly during pilot-scale processing than the club wheat used in previous studies, both for the production of canned whole-grain bulgur and the seasoned bulgur, called pilaf. The peeled red wheat kernels, however, were much less prone to disintegrate during the high temperature cooking phases and gave quite a satisfactory texture in the final product. This resistance to overcooking is probably a function of the higher protein content of the red wheat as compared to the club wheats which are normally quite low in protein.

Discrimination and acceptability tests conducted by the Agricultural Marketing Service with our cooperation on whole-grain and cracked grain pilafs prepared at two levels of seasoning from the hard red winter wheat showed that untrained tasters could not reliably distinguish between the two levels of seasonings used. Acceptability by untrained tasters totally unfamiliar with the products was moderate, a rating received rather frequently for a new product which later becomes well received. The full kernel form of the product received a small edge in preference.

The effect of moisture content of conventional dry bulgur on the degree to which it expands during a hot-air puffing operation was determined. Puffed volume increased regularly as moisture content decreased from 14% to 8%, consequently, the behavior of bulgur in this respect with a maximum at or below 8% moisture is different than that of rice. In later studies optimum conditions for heat-expanding bulgur have been found to be 500-600°F. air temperature, 400-600 f.p.m. air velocity, 7 to 11% moisture, and bran removal equivalent to about 40% reduction in crude fiber content of the bulgur. Of these variables, only degree of debranning showed any effect on rehydration properties of the puffed material. Instant bulgurs prepared by heat-puffing are suitable for use in dry dessert mixes, dry soup mixtures, salad mixtures, and the like. Commercial formulas for pineapple, butterscotch, and chocolate flavored Bavarian puddings have been developed and are undergoing storage stability tests. Mild toasting of the bulgur for the butterscotch and chocolate puddings is desirable, but not for the pineapple pudding.

Commercial formulations and processing procedures for eight new canned bulgur products are virtually completed. Whole-kernel bulgur was found to be a better starting material for such products than

peeled raw wheat, especially if the products are unflavored or mildly flavored. Special precautions were found necessary for control of kernel texture in canned products containing sugar or acidic materials such as tomato puree.

More than twenty common bleaching agents have been screened for their effectiveness in whitening partially debranned red wheats in development of bulgur-like products of lighter color and blander flavors for overseas markets. Heat treatment of raw wheat prior to bleaching markedly reduces cooking time of the final product. The bleached wheat has been given the name "wheat pearls."

Engineering studies have been carried out in two areas, continuous bulgur production processes, and wheat peeling. In these investigations, pilot-plant studies have led to development of a simple continuous process for production of dried precooked wheat (or bulgur). In this process, cleaned wheat is soaked and precooked in four simple conveyor-type units connected in series. In the first two conveyor units, the wheat is soaked for a total time of about 60 minutes in water ranging in temperature from 140° to 180° F. The grain is then drained and held hot in the third conveyor unit for a 30-minute tempering period. The tempered grain is fed to a wire-mesh conveyor belt on which it is cooked in steam at atmospheric pressure for 15 minutes. The cooked grain is then dried by conventional means. Studies to determine optimum conditions for applying this simplified process to different types of wheat are in progress.

In the area of wheat peeling, laboratory and pilot-scale studies are being made to determine the effects of processing variables in debranning of raw wheat. These studies involve use of milling equipment of the type used in processing of rice and include milling of red and white wheats with and without the addition of water and mild abrasives. Considerable information has been obtained on conditions required to obtain different degrees of debranning. With either moisture conditioning or addition of mild abrasives, or both, more bran can be removed than by either wet scouring or dry milling techniques previously employed. A concomitant unexpected advantage is that much of the germ is also removed by these techniques, a result never before accomplished without subdividing the kernel. A procedure has been found that effects essentially complete removal of colored bran layers from red wheat, but the milling times and weight losses are as yet undesirably high.

2. New Food Products from Gluten. In early exploratory work it was shown that textures and flavors satisfactorily similar to meat products can be achieved by appropriate combinations of wheat gluten, high-protein wheat flours, cracked bulgur, and various appropriate seasoning materials derived from either or both vegetable and animal

protein hydrolysates and extracts. Commercially available wheat gluten, obtained almost entirely from second-clear flours, was found to be too dark and too strongly flavored to be suitable for products simulating veal or chicken products. Glutens washed from baker's patent flours, however, are quite satisfactorily light in color and bland in flavor. Texture modifications have been obtained by appropriate partial denaturation of gluten before incorporation into products and/or by blending with flour or with cracked gluten of differing size-grades. Combinations of appropriate commercially available flavoring materials have been devised to simulate closely, beef-, chicken-, veal-, and fish-flavored products.

Additional work with handmade meat-like combinations based on gluten has shown that texture modifications of formulations resembling loaves, patties, or chopped steaks can be obtained by manipulation of moisture levels and proportions of cracked bulgur or high-protein wheat flour blended with the gluten. Preliminary trials with canned products, such as a vegetable stew containing beef-like chunks of gluten, indicated that no special difficulties need be expected except that texture control may need extra attention. The formulated products also freeze well provided waxy rice or waxy corn starch comprises part of the thickener used for sauces or gravies.

3. Biological Value of Processed Wheat. Studies aimed at developing rapid chemical methods for assay in the biological value of proteins during processing of wheat food products, is being conducted under P.L. 480 at the University of Cambridge, Cambridge, England. Results to date show significant apparent losses in amino acids other than lysine when proteins are heated at moderate temperatures. Excellent results are being obtained in this very timely research which will guide further research aimed at developing foods to alleviate nutritional inadequacies around the world.

4. Products from Air-Classified Flours. In cooperative studies with the Northern Utilization Research and Development Division, baking evaluations and soluble protein analyses were conducted on 15 samples of flour derived by fine grinding and air-classification of pastry flour commercially milled from the Pacific Northwest club wheat. Three blends containing 11.5 to 12.0% protein produced very poor bread. A low protein hard red winter wheat flour enriched with a high-protein air-classified club wheat fraction also produced very poor bread. Six of the seven blends of the air-classified fractions suitable for cake flours, produced good white cakes after bleaching; the seventh, a coarse residue fraction, produced a fair cake. The reground coarse residue, however, produced good cakes. The flour blends designed for cookies produced very good, good, fair, and very poor cookies. The contents of total soluble proteins,

total albumin, and total globulin in the original flour were consistent with results obtained previously for flours of a similar type. Protein shifts caused by air-classification did not alter the characteristically low albumin/globulin ratio of the original flour, although the percentages of the soluble proteins varied inversely, but moderately, with the total protein content of the fractions obtained.

In extending these studies to other wheats, flours milled from the varieties Brevor, Burt, Rio, and Omar were fractionated by air classification at the Northern Regional Research Laboratory and evaluated at the Western Regional Research Laboratory. Fine fractions containing 15 to 26% protein were combined with each of 3 medium-protein flours (9.7, 10.3 and 10.7% protein) to give blends containing 12% protein. Bread loaf volume and score were increased most by the Brevor fractions, followed by Rio; they were not changed by Omar fractions and were decreased by Burt fractions. Water absorption was markedly higher (6.2% over-all average) for the blends than for the base flours. Burt fractions gave the largest increases, followed by Rio; the increases parallel starch granule damage. Stability of the blends to mixing in the Farinograph was only slightly changed.

Better cookies were obtained from Brevor and Omar samples than from Rio and Burt. Within varieties, however, marked differences were found in which granulation must be a factor. Thus regrinding coarse fractions or the original flours resulted in large decreases in cookie spread. Nevertheless, there was no definite limit in particle size below which spread was poor, and fine fractions from the Brevor wheat gave high spread values.

Cakes were baked (after chlorine bleaching to pH 5) from low-protein fractions. With the methods used, no obvious trends were found. In general, however, good cakes were not obtained with coarse fractions that gave viscous batters.

5. Wheat Flour Lipids. The effects upon baking quality of composition variations in wheat flour lipids is being investigated under P.L. 480 at the British Baking Industries Research Association in Chorleywood, Herts, England. The effect upon baking quality of added fat, of location of growing of wheat, and effect of nitrogen fertilization are all being investigated. Thin-layer chromatography is being utilized to compare lipids in the flour, dough, and bread. The U.S. wheats under investigation are being supplied by the Western Utilization Research and Development Division.

6. Food Supply in Fallout Shelters. Investigations on processed foods suitable for provisioning fallout shelters are being conducted using funds transferred to Agriculture by the Department of Defense.

Two lines of research are involved; (1) Extension of research on the bulgur-type wheat wafer previously conceived by the Western Utilization Research and Development Division for stockpiling in fallout shelters, and (2) development of a line of adjuncts for use with the bulgur-type wheat wafer.

Wheat bulgur wafers are composed of about 80% puffed bulgur, 10% shortening, 10% malt sirup solids and a small quantity of salt. The ingredients are warmed, mixed, and pressed in a die using several tons pressure. The protein content of the wafer is fixed at 7.5 to 8.5%, a level established as the optimum for situations where water intake is limited.

From information obtained from experimental production on a laboratory scale, a commercial-scale production line has been proposed and cost estimates prepared. Several variations in wafer formulations and methods of preparation have been investigated. Some of the changes in formulation are included in the storage stability studies to be conducted under the contract discussed below. Cookie-forming equipment, extrusion presses and similar equipment using dampened mixes were found to produce wafers substantially lower in density than those formed by pressing.

To determine the effectiveness of changes in formulation on relative stability, accelerated test methods were used. The Oxygen Bomb Stability Apparatus failed to produce usable results. A new approach has been made toward an accelerated test method for bulgur wheat wafers by employing gas-liquid chromatography (GLC). Combining the oxygen bomb for treatment of the sample and GLC for measuring changes gave promising results in preliminary tests. For example, GLC measurement of hexanal increased in samples treated in the oxygen bomb for increasing time periods. Similarly, the samples protected with increasing amounts of antioxidants showed decreasing amounts of hexanal for equal treatment in the oxygen bomb.

A research program for evaluating the stability of wafers by taste panel methods on samples stored at three temperatures, 40, 70 and 100° F. over a five year period was developed and initiated by contract with Oregon State University. Sixteen different formulation package combinations will be studied representing a complete factorial of four variables, (1) red and white wheat, (2) pressure cooked and atmospheric cooked bulgur, (3) malt sirup and corn sirup binder, and (4) air and nitrogen atmospheres in the package. Simultaneously chemical analyses will be performed, selected on the basis of their usefulness in measuring changes which may be related to wafer quality and useful in predicting shelf life of wafers.

The wafers offer unusual versatility in use. It may be eaten out of hand, plain, or with spreads or icings and it may be crumbled

for use with soups, sauces, gravies, and toppings to provide a diversity of dishes. A number of adjuncts for use with the wafer have been developed. These are dehydrated mixes that may be readily reconstituted for use. Preliminary formulations for nearly 60 different foods were developed. Evaluations and modification of formulas are to continue.

C. New and Improved Food Processing Technology

See, under paragraphs B, 1 through 6, product development work that is related to improved processing technology.

D. New and Improved Feeds

1. Estrogens in Wheat Bran and Germ. Contract research is underway at the State University of Iowa, Ames, Iowa, to determine the chemical nature of potentially estrogenic compounds that can be isolated from wheat germ and bran as a basis for the development of products of enhanced value in the fattening of livestock and poultry. This work is a part of a fundamental approach to upgrading non-flour fractions of wheat. These fractions which comprise about 30% of domestically-milled wheat have been sold conventionally as feed components. Markets were lost in feeds for non-ruminant animals due to the current trend to higher energy in this type of feeds. Development of specific uses due to biologically active components can be expected to increase their dollar value and thus increase the overall value of the farmer's product.

In earlier work the ether-extractable non-saponifiable constituents of wheat germ were fractionated into four major groups by chromatography on alumina columns. These groups were: a) a hydrocarbon fraction, b) a carotenoid fraction, c) a high-melting steroid (m.p. 160-165° C.) fraction, and d) a "beta-sitosterol" fraction (m.p. 130-140° C.). Gas chromatography of the hydrocarbon fraction revealed nine major and almost twenty minor peaks. Similarly, four peaks not well separated were found in the steroid fraction. Bioassays of the steroid fraction and of two arbitrarily selected portions of the "beta-sitosterol" fraction showed no estrogen-like activity.

The non-saponifiable constituents of bran oil were separated into five fractions: a) a hydrocarbon fraction, b) a "middle" fraction, c) a steroid fraction, d) substance A (crystalline), and e) an end fraction. Refractionation of the middle fraction by chromatography on alumina separated it into four fractions: 1 and 2 were oils of distinct infrared absorption patterns, 3 substance A, and 4 "beta-sitosterol" fraction (m.p. 130-138° C.). Fractionation of the bran non-saponifiables on the basis of alcohol solubility and refractionation by chromatography on alumina leaves small amounts of substance A in most of the other fractions. It can, however, be

recovered from the other fractions by use of a special extraction procedure employing Claisen's alkali and petroleum ether. Preliminary bioassays indicate that both substance A and the hydrocarbon fraction possess estrogen-like activity. Initial attempts have been undertaken to determine the structure of substance A. A preparation showing only one spot on thin-layer chromatography analyzed $C_{14}H_{26}O$ (or $C_{28}H_{52}O_2$). An observed molecular weight of 437 compares well with the weight of 421, calculated for the dimer. Infrared and ultraviolet absorption spectra have been obtained on the original molecule and its crystalline acetate. Nuclear magnetic resonance spectra have also been obtained on the acetate derivative. Elemental analyses on the compound and its acetate limit the forms to $C_{25}H_{44}O_2$ or $C_{26}H_{46}O_2$ formulas. This suggests it to be a long-chain alkyl dihydroxybenzene. Crystallization of the almost pure acetate derivative from methanol reverted it to mixtures. Thin-layer chromatography revealed that relatively rapid solvolysis was taking place and that the mixture contained the original acetate, an intermediate substance, and substance A. Furthermore, it could be shown that both acetylation of the latter and hydrolysis of the original acetate leads through a single intermediate--the first indication that a dihydric phenol of symmetrical structure might be involved. These data, the nuclear-magnetic resonance data, and a reasonable biosynthetic assumption of substance A being of polyacetate origin form possible structures differing only in the symmetrical ortho or meta position of the two hydroxyl groups to the long alkyl chain having either 19 or 20 carbon atoms. Ozonolysis of substance A has yielded an acid, crude m.p. 68-72°. While this compound is still in a crude state, it may be of significance in that its melting point is in the range close to those of stearic (C_{18}) arachidic (C_{20}) and behenic (C_{22}) acids.

E. New and Improved Feed Processing Technology

1. Upgrading Wheat and Barley Feeds. It had been demonstrated earlier that nutritional properties of grains can be markedly improved by laboratory-scale processing treatments with water and with enzymes. Basic knowledge was lacking, however, of the chemical changes occurring in these grains during these new treatments. Such information is essential for development of commercially feasible processes. Contract research in this area has been recently completed at Washington State University, Pullman, Washington. Based on this study it appears that economical methods can be developed for treating western-grown cereal grains and products derived from them in order to obtain their maximum feed value in high-energy growth rations for chicks, and further, to discover the mechanisms by which the improvements are obtained. In the work reported previously it was noted that the largest part of the positive effect of water treatment of barley and wheat and their fractions was due to combined effect of enzymes, and antibiotics produced by

microorganisms of the B. Subtilis type, which grew during the slow-drying process used on the wetted grains. More recent results are not completely in agreement on this point. For chicks, the weight of evidence is still in this direction. For turkey poults, however, newer results have shown that water treatment gives a greater effect than bacitracin plus fungal amylase. Furthermore, an additional response was obtained by feeding terramycin in either case. It is noted also that in chicks, wheat bran was improved more by water treatment than by the antibiotic, bacitracin, plus fungal amylase supplementation. The importance of microorganisms in the barley water treatment on the effect on growth was clearly demonstrated by experiments utilizing ethylene oxide sterilization. An additional important point that was clarified by these studies was the following: feeding barley was found to cause hypertrophy of the pancreas but this effect was reduced by water treatment of the barley.

Very little effort was possible "in-house" because of efforts expended on other high priority research. It was demonstrated, however, that supplementation with commercial enzyme mixtures and zinc bacitracin of high-energy broiler rations containing various wheat fractions failed to overcome the small but significant growth inefficiencies previously observed in chicks fed rations high in the endosperm fraction of wheat. Growth rates on diets containing about 48% of second middlings or second low-grade flour stocks were as low or lower than those for diets containing 30% of bran or germ. Much of the growth diminution obtained on the latter diet is directly attributable to their high fiber content. Responses to the enzymes plus antibiotic additions were either negative or only very slightly positive on all diets. The greatest response was obtained on the whole wheat diet.

The results obtained contrast with those found for barley on which starch digestibility and availability are improved as much by the enzyme plus antibiotic additions, as by water treatment. Thus the possibility still exists that some deleterious substance is present in wheat endosperm, although water treatment of such fractions must still be investigated before the digestibility hypothesis can be eliminated with confidence.

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III. MARKETING RESEARCH

MARKET QUALITY

Market Quality Research Division, AMS

Problem. Grain and cereal products are subject damage or deterioration in quality while in marketing channels through normal metabolic changes, by the action of micro-organisms, and by the attack of more than 50 species of stored-product insects. Safe storage of grain, flour, and cereal products for extended periods is a problem of immediate concern to military and civilian defense agencies. To maintain the quality of these products, more precise information is needed on the changes that occur in handling, storage, and transportation of these materials and of the products manufactured from them. To insure uniform and standardized products in the marketing channels and more equitable prices to all concerned, new and improved methods and techniques for measuring quality factors need to be developed for use in the inspection, grading, and standardization procedures. There is urgent need for more effective methods for preventing insect damage and contamination during storage, handling, processing, packaging, transportation, and retail distribution. The need is critical for effective pesticides and application methods that can be used in the marketing channels without leaving objectionable residues. Even more desirable is the development, wherever possible, of effective preventive and control measures utilizing biological, physical, mechanical or other non-chemical means that would reduce or completely eliminate the application of pesticidal chemicals.

USDA PROGRAM

The Department has a continuing program involving chemists, engineers, and plant pathologists in basic and applied research on the quality evaluation, quality maintenance and development of objective methods for quality evaluation of cereal grains. The research is conducted at Beltsville, Md., and Watseka, Illinois, and also by research contract with Shuman Laboratories, Battle Ground, Indiana and with Doty Laboratories, Kansas City, Mo.

The program includes the following foreign projects under PL 480: A grant to the Israel Institute of Technology, Haifa, Israel, provides for a study to develop quality tests for cereal grains and feeds. Its duration is 4 years, 1960-1964, and involves PL 480 funds with a \$103,785 equivalent in Israeli pounds.

A grant to the Agricultural Higher School, Poznan, Poland, provides for a study of the effect the microflora of wheat flour on its stability, biochemical, and technological properties. Its duration is 4 years, 1961-1965, and involves \$13,091 equivalent in Polish zlotys.

Also there is a continuing long-term program involving entomologists and chemists engaged in both basic and applied research on problems of insect infestation, damage, and contamination of grains and cereal products in the marketing channels. The work at Manhattan, Kansas, and Tifton, Georgia, is in cooperation with the respective State Agricultural Experiment Stations. The work at Manhattan, Kansas, Savannah, Georgia, and Watseka, Illinois, is in cooperation with the Agricultural Stabilization and Conservation Service

and one man-year of effort is supported at each of these locations by Commodity Credit Corporation funds. There is cooperation with growers cooperative associations at Manhattan and with various industry groups at all locations. There is also overall cooperation with the State Experiment Stations in Regional Project WM-16, "Maintaining Grain Marketability by Insect Control in Storage."

The work at Savannah, Georgia, has cross-commodity application. The entire program is discussed in Area 13. Although almost all the work on insecticide evaluation, insecticide residue analysis, and insect-resistant packaging has a direct relation to the insect problems in grain and cereal products, only a proportionate share of the man-power has been allocated to Area 4.

Contract research includes work with the University of Georgia, Athens, Ga., and with Auburn University Agricultural Experiment Station, Auburn, Alabama.

A contract with the Hebrew University in Rehovot, Israel, provides for extensive studies on the effect of ethylene dibromide-fumigated feed on domestic farm animals. It became effective in September 1961 and continues for 3 years. It involves PL 480 funds equivalent to \$98,197.

Another contract with the Hebrew University at Jerusalem, Israel, is for a study of the influence of environmental conditions on the population dynamics of the khapra beetle. It became effective in October 1961 and continues for 3 years. It involves PL 480 funds equivalent to \$44,296.

A contract with the Ministry of Food and Agriculture, Karachi, Pakistan, is for the evaluation of insecticides applied to bulk stored grain as control or preventive measures against the khapra beetle. It became effective in 1962 and continues for 5 years. It involves PL 480 funds equivalent to \$79,570.

A contract with the Administration of Agricultural Reserves and Surpluses, Montevideo, Uruguay, is for the study of underground storage of corn in air-tight silos in relation to maintaining quality and preventing insect infestation during long-term storage. It became effective in May 1962 and continues for 5 years. It involves PL 480 funds equivalent to \$59,906.

The Federal scientific effort devoted to research in this area totals 27.2 professional man-years. Of this number, 7.3 is devoted to quality maintenance and evaluation; 2.4 to basic biology and ecology, 2.4 to insecticide evaluation, and 1.2 to insecticidal control at Manhattan, Kansas; 1.0 to insecticidal evaluation at Tifton, Georgia; 1.0 to insecticidal control at Watseka, Illinois; 2.8 to insecticide evaluation, 2.0 to insecticide residue analysis, and 2.6 to insect-resistant packaging at Savannah, Georgia; 2.3 to program leadership at Beltsville, Maryland; and 2.2 to contract research.

There has been an extensive modification of the research program on stored-grain insects during the reporting period. Previous work has been almost exclusively of a practical or applied nature. In a critical evaluation of the program, it became apparent that some of the work was being impeded by the lack of foundation information of a basic nature. Because of the serious

lack of basic information on the biology, behavior, ecology, physiology, and nutritional requirements of stored-grain insects, it was decided there should be a shift of program to some of these lines as rapidly as possible, without eliminating necessary applied studies.

Sixteen line projects have been discontinued during the reporting period, most of them as a result of shift in emphasis of program. These were: protective treatments for grain (BS 1-34, BS 1-61, and BS 1-44(C)); grain fumigation studies (BS 1-35, BS 1-36, BS 1-60, and BS 1-87); insect control in country elevators (BS 1-40, BS 1-41, and BS 1-42); study of dermestid beetles in grain (BS 1-43); insect problem in corn and oats in the Southeast (BS 1-58 and BS 1-59); an evaluation of the thermal aerosol application of insecticides to stored grains (BS 1-83); deterioration of dry beans during marketing (BS 2-160); and fat acidity as an index of soundness in grain (BS 3-55).

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Stations in 1961 reported work on market quality of grain, rice, feed, and seed as a unit. The combined professional man-years for the unit was 23.4. Of this 9.6 was on objective measurement and evaluation of quality, 0.8 handling and packaging, 2.5 storage, 0.1 transportation, 5.8 post-harvest physiology, and 4.1 insect control.

Industry and other organizations conducting research on these products included large milling companies on milling and baking properties, on storage and handling, and on insect control; feed companies on blending feed ingredients, particularly micronutrients, and on sampling procedures; seed companies on seed germination, seed vigor, and seed quality measurements; and chemical companies on synthesis, development, and formulation of new pesticides and fumigants. Total estimated annual expenditures were equivalent to approximately 28 professional man-years, or about 10 man-years for grain alone.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Objective measurement and evaluation of quality.

1. Test for Heat Damage in Corn. Increased artificial drying of corn has resulted in quality problems such as increased friability in handling and impaired usefulness for wet or dry milling. In the search for a quick test for heat damage, many chemical and physical methods have been investigated. An inverse relationship between reducing-sugar content and drying temperature (120°-200° F.) was found in four of the five sample groups studied. In all samples, diastatic activity decreased with increase in drying temperature. Statistical analysis of all samples yielded a highly significant correlation of diastase activity with temperature. However, the data indicated that the technique could not be used in its present form in assaying heat damage. Shuman Laboratories, of Battle Ground, Indiana, have examined artificially dried samples of corn from a pilot wet milling procedure, by a starch yield test using a sectioning technique and for lysine and tryptophan. No single analytical test has been found to predict wet millability as related to drying temperature although the laboratory wet milling procedure yields information of predictive value.

The design of an impact tester to measure the fragility of corn has been completed. The machine consists of an impeller with a five-inch radius of rotation which throws kernels of corn against a steel cylinder that surrounds the impeller.

Studies have shown that harvesting corn at high moisture contents and subsequently drying it with heated air can cause the kernels to become more fragile than the kernels of corn dried with natural air either in the field or after harvesting. In general, corn dried with natural air had breakage of about five percent while corn cured with air heated to 160° F. or more had breakage of about ten percent when subjected to breakage tests at thirteen percent moisture content.

There is a correlation between the number of stress cracks in corn kernels and their fragility. Corn kernels dried at temperatures above 110° F. have a large number of stress cracks and a high degree of breakage while kernels that are dried with unheated air have no stress cracks and a relatively low degree of breakage.

There is a definite relationship between moisture content and the fragility of corn. Field dried corn had ten percent breakage at ten percent moisture content and two percent breakage at fifteen percent moisture content. There appears to be a straight-line relationship between breakage and moisture content within this range.

2. Quality Indicators for Stored Wheat. Under contract with Doty Laboratories, quality tests were performed on stored wheat. Samples of Northern Spring wheat (Selkirk) and Hard Red Winter wheat (Comanche) obtained from the 1960 harvest were placed in storage at 75° F. and at moisture contents of 16, 14, and 12%. Samples were removed and examined for Federal grade, sedimentation, germination, fat acidity, protein content, and moisture, plus analyses conducted on flour from each sample (protein, ash, moisture, maltose, Farinograph, Extensograph, and baking tests). After nine months' storage, the Spring wheat at 16% moisture had declined in germination and sedimentation with corresponding increases in fat acidity values and a decline in baking scores. Fourteen percent moisture samples showed a similar but slower change. Twelve percent moisture samples retained their quality. The Hard Red Winter wheat samples followed essentially the same pattern but at a slower rate.

3. Standardized Lighting Conditions for Grading Grain. At the request of the Grain Division, AMS, work on an acceptable artificial light source for grain inspection was started. In a study of four light sources, an artificial North Sky Daylight was used as standard with conditions of viewing a 45° angle and a 130 foot candles intensity at the viewing surface with a neutral grey surround. It was found that test lamp number 1 (Macbeth TC 440 examolite) would be suitable for inspection purposes. The study was conducted by having 17 individuals who had been screened for color perception compare color chips comprising wheat and corn colors under the standard and under each of the test lamps by a fixed procedure. The ability of these test panelists to correctly match colors under the standard and test light source was the measure of efficiency of the source. Preliminary work on selection of a color background

for inspection indicated that colors complementary to the color of the commodity being examined will be preferable to backgrounds of matching color.

4. Fat Acidity. The study of the fatty acid composition of the oil from damaged corn and wheat was completed. This limited study contributed some knowledge to the understanding of the free fatty acid composition of damaged grain. A manuscript on this subject has been accepted for publication.

5. Sampling Methods. Progress has been made on a plan for cooperative grain sampling research with the grain industry, grain sampler manufacturers, and the grain inspection service. This plan provides for mechanical sampling of boxcar quantities of grain at country loading points and probe sampling of the same loads while enroute to terminal elevators. A tentative procedure for evaluating the performance of various sampling methods and devices has been prepared.

6. Moisture Determination in Grain. A study was carried out in which a comparison was made of the results obtained by the more important "basic" methods for moisture determination in seeds. The methods studied were Karl Fischer, near-infrared spectro-photometric, vacuum-phosphorus pentoxide, toluene distillation and air-oven methods. Seeds used included corn, wheat, barley, soybeans, flaxseed, peanuts, seven grasses and eighteen vegetables. The methods were also evaluated on the basis of accuracy, time and skill required.

An investigation was initiated to determine whether or not the amount of inorganic salts present in wheat is a factor accounting for the deviations from oven moisture results which occur when moisture is determined on the Tag or Motomco moisture meters. There appeared to be some correlation between deviations and inorganic salt content but it was not enough to justify further work.

The near-infrared spectrophotometric method of moisture determination has been applied successfully to the methanol extracts of grain. Attempts to use the method directly on the grain itself, have not been completely successful, but do show promise provided an instrument better suited to the procedure can be built.

7. Measurement of Flour Yield of Wheat. Limited tests, using a weighed-wheat-volume sample with an air-comparison pycnometer, suggest that density of the wheat may indicate the yield of the flour produced therefrom.

B. Quality maintenance in storage.

1. Corn. Studies of storage behavior of corn dried to 0, 4, and 8% moisture and in atmospheres of 0, 5, and 20% oxygen at 3 storage temperatures of 1°, 20°, and 50° C. indicate that drying to low moisture levels is feasible but costs and damage inflicted below 2% moisture limits practicality of such low moisture drying. Moisture contents of 2 to 4% appeared to be feasible and resulted in extended storage life with little loss in vigor and viability in these storage studies of two years duration.

Construction of facilities during fiscal year 1962 made possible initiation of studies of microbiological deterioration of corn in storage during the current year at Watseka, Illinois. Examination of some 200 samples from two bins of 1960 crop year blended corn indicated wide variation among the samples in (a) fungus population, (b) germinability, and (c) moisture content.

In a study of corn in two quonset buildings, data indicate that an exhaust system of aeration was not as effective in maintaining quality as was a forced air system. In March 1962, average germination of corn was 63% when aerated by the forced air system vs. 26% when aerated by the fan exhaust system. Striking differences in populations of Aspergillus and Penicillium were evident. A study of grain storage in plastic bags indicated that this storage was unsatisfactory due to failure of the plastic used.

2. Wheat. In a study of the effect of microflora of wheat flour on its stability, biochemical and technological properties, 68 samples of wheat harvested in 1961 representing all climatic and soil regions of Poland were collected and are being examined for surface and interior infestation with bacteria and molds. Vegetative forms of aerobic bacteria were dominant on the exterior of the grain but occasional interior infestation was evident. Eighty-four percent of the samples showed internal infestation with fungi. Sixty-two different bacterial species and 58 fungus species have been isolated. These organisms are being identified with particular emphasis on determining bacterial species which might be injurious if they contaminated wheat flour. The investigation will be continued.

C. Quality maintenance in transportation. An export study which has been published as MRR 519 entitled, "Maintaining Quality of Pea Beans During Shipment Overseas," contains information on quality maintenance of grain in transportation. In this study, 3 shipping tests were made with Michigan pea beans in 100 pound burlap bags from loading points in the Great Lakes area through the St. Lawrence Seaway to ports in Western Europe. Data on moisture and temperature changes within the holds showed the importance of proper aeration of the hold to prevent moisture increase and mold development in transit.

D. Prevention of insect infestation.

1. Basic Biology and Ecology. Research was initiated at Manhattan, Kansas, in 1962 to study the preconditioning effects of nitrogen and carbon dioxide on the susceptibility of stored-product insects to fumigants. Pure nitrogen appears to be more toxic to confused flour beetle adults than is pure carbon dioxide. This was contrary to what was expected from literature reports. Nitrogen killed 50% of the beetles in 5.5 hours, and carbon dioxide gave the same kill in 7.5 hours. Nitrogen killed 99% of the beetles in 9 hours and carbon dioxide killed 99% in 12 hours. Over 200 respiratory analyses were made of adult flour beetles by means of gas chromatography. These are the first such measurements on record. They provide information on the metabolism of the insects, which gives a criterion other than subsequent fumigant mortality for judging the efficacy of a preconditioning factor.

A study has been initiated on the effects on insects of air movements such as occur during the aeration of grain in bins, but there are no results to report as yet.

A study was initiated in 1962 to investigate the ecological aspects of varying amounts of foreign material, dockage, and moisture in wheat and corn on the biology of stored-grain insects. Studies thus far have been with the confused flour beetle. Preliminary data show that about the same number of insects were recovered from clean wheat and that with 0.3% dockage. Twice as many were recovered from wheat containing 4.5% dockage, more than 3 times as many from that with 9% dockage, and more than 5 times as many when there was 13.5% dockage.

A contract with the Hebrew University in Jerusalem, Israel, to determine the individual and combined effects of various environmental factors on the biotic potential of the khapra beetle, is in its early stage, and there is no progress to report.

2. Insecticide Evaluation. Synergism in repellency was demonstrated for the first time against a stored-grain insect. Test insects exhibited little or no response to wheat treated with either allethrin or piperonyl butoxide. When the two materials were combined the insects were definitely and strongly repelled. Finely divided diatomaceous earths applied to wheat at the rate of 2 to 12 pounds per ton were repellent to test insects. There was a strong correlation between particle size and repellency. The finer dusts with an average particle size of 0.8 microns were more repellent than those with particles of 1.0 to 10.0 microns, especially at lower dosages. Of the candidate repellents received from the Savannah station, the most effective one on wheat was m-dinitro benzene.

A series of replicated tests with synergized pyrethrum, premium grade malathion, and a diatomaceous earth applied as protective treatments to wheat, corn, and grain sorghum has been concluded at the end of one year. During that time the grain in small 5-cubic-foot bins was constantly exposed to infestation by several kinds of stored-grain insects. A 57-percent malathion emulsifiable concentrate applied at the rate of 1.5 pints per 1,000 bushels gave excellent protection against infestation to corn and wheat for 12 months but not to grain sorghum.

A proportionate share of the insecticide evaluation work of a cross-commodity nature at Savannah, Georgia, has been charged to this area although most of the work is directly applicable. It is not feasible to report only certain portions here, or to include all the information under each commodity area. The entire report is included in Area 13.

3. Insecticidal Control. A large scale test in which wheat was treated with several different candidate protectants was concluded at the end of 62 months. Methoxychlor was the only treatment that lasted for the duration of the test and only some of the bins of wheat treated with this material survived.

A number of elevator bins of wheat were treated with liquid fumigant using four different application methods. These were: (1) entire dosage on surface of filled bin, (2) dosage divided between half-filled bin and surface, (3) dosage divided between 5,000-bushel layers, and (4) dosage divided between 1,000-bushel layers. Evaluation of effectiveness was based on mortality of test insects, and on gas distribution as determined by chromatographic analysis of air-gas samples drawn from different points in the bins. The number of replications was not great enough to give statistically reliable data but the indications were that the total surface application gave the best results, followed by the other methods in the order just listed. Considerable fumigant mixture component separation occurred at the lower levels of all tanks during the 48-hour gas-sampling period following application of the fumigant. Gas analysis indicated as much as a 20:1 ratio of carbon tetrachloride to carbon disulfide whereas the ratio as applied was 4:1. Component separation did not seem to vary appreciably between methods of application.

Laboratory-scale fumigations were set up using 6'x8" circular metal towers as simulated elevator tanks to repeat the preceding comparison of application methods, each method being run 3 times. The effectiveness was in the same rank as had been found in the full-scale elevators.

In conducting elevator fumigation tests it was found that low gas concentrations and insect kill occurred in the outer part of the bins, indicating poor lateral dispersion of the fumigant. Elevator employees tended to place the fumigant at one side or the center of the bin. The fumigant should be distributed over the surface of the grain in relation to the underlying volume. For example, in bins of the size used in these tests the part covered by a 6-foot radial periphery represented over 70 percent of the total volume.

A series of identical structures for flat storage of grain was fumigated with a mixture of methyl bromide and chloropicrin to compare the effectiveness of gravity penetration, single pass, and closed-recirculation methods of application. The results of these tests clearly demonstrate the superiority of the closed-recirculation method in obtaining uniform distribution of the fumigant and in producing a significantly higher rate of mortality of test insects throughout the grain mass. The closed-recirculation method was also superior for applying a liquid fumigant of the 80:20 carbon tetrachloride-carbon disulfide type, as indicated by higher mortality of test insects throughout the grain mass and by the more uniform distribution of the fumigant. In the gravity penetration fumigation there was not only less uniform distribution but considerable variation in the carbon tetrachloride-carbon disulfide ratios at different locations in the structure.

In tests on the effectiveness of phosphine fumigation where there is a temperature differential between the grain in the center and at the periphery of standard circular metal bins, two aluminum phosphide tablets per ton of wheat or shelled corn gave complete kills of introduced test insects in all parts of the bin except near the lower door where gas concentrations were low. Increasing the dosage to 6 tablets per ton, which is the label recommendation, gave complete kill at the doorway. Tests in which an 80:20 fumigant was probed

into so-called "hot spots" at the rate of 5 gallons per 1,000 bushels of shelled corn did not give effective results. There was poor kill of insects in the "hot spot" area and gas analyses indicated the fumigant vapors fell rapidly through the grain to the floor of the bin and then crept to the bin walls.

A PL 480 project with the Ministry of Food and Agriculture, Karachi, Pakistan, has just been initiated to study protective treatments against the khapra beetle in grain. There is not yet any progress to report.

A contract has just been initiated with the Auburn University Agricultural Experiment Station to study insect damage to harvested corn in the Southern states and to assess the value of insect control measures now used for preventing such damage. There is not yet any progress to report.

4. Nonchemical Control. Observations at Watseka, Illinois, are that fewer insects are generally present in shelled corn in aerated standard circular metal bins than in nonaerated bins. The latter require a protective treatment or at least an annual fumigation to keep insects under control. In some cases aerated bins have not required fumigation for 3 or 4 years. The majority of insects found in aerated bins are on or near the floor below the level of the vertical aeration duct. Insect population trends were also observed in two identical aerated flat storage structures containing shelled corn. One aeration system was operating in the normal way, pulling air down through the corn. In the other building the fan was reversed to force air up through the corn. There were very few insects in this corn. Where the normal aeration pattern was followed there were a considerable number of insects present at the corners of the building.

A PL 480 project has recently been initiated with the Administration of Agricultural Reserves and Surpluses in Montevideo, Uruguay for a study of the efficacy of underground airtight storage in maintaining the quality of corn and preventing insect infestation during long-term storage. No results are yet available.

5. Toxicology. Under a contract with the University of Georgia, it was found that egg production was not affected by 4 mg. of ethylene dibromide (EDB), equivalent to 40 p.p.m. of the total diet, but was reduced significantly by 8 mg. per day. Production was stopped completely in 7 weeks by 16 mg. per day. Egg weight was more sensitive and as little as 0.5 mg. of EDB per day caused a slight reduction in egg weight. One mg. or more per day caused significant reduction. Ethylene dichloride (EDC) and carbon tetrachloride had no effect on the rate of egg production, either alone or in combination with EDB. Their effect on egg weight however appeared to be slightly additive in combination with EDB. Slightly greater mortality in groups receiving carbon tetrachloride, either alone or in combination with EDB and EDC, suggested the toxic nature of this material at the levels fed. EDB was equally toxic to young pullets and old hens. Autopsy of birds whose rate of egg production was affected by EDB revealed ovaries containing an excessive number of incompletely developed follicles, suggesting an interruption of neurohumoral

control of the growth and shedding of the ova. Microscopic examination of brain, liver, and kidney tissues revealed no histological changes that could be associated with experimental treatments.

Results on the effects of ethylene dibromide (EDB) in the diet, on the growth of chicks is included in a manuscript by G. K. Morris and H. L. Fuller, now in press, for early publication in Poultry Science. A reduction in weight gains, feed consumption and feed efficiency occurred when the diet at time of feeding contained 40 p.p.m. or more of EDB. Chemical analysis of the kidney and liver tissues of chicks receiving 280 p.p.m. of EDB in their feed for 2 weeks revealed about 50 p.p.m. of bromides, which is equivalent to 120 p.p.m. of EDB. No additional deleterious effects were observed when ethylene dichloride and carbon tetrachloride at levels of 1280 and 2560 p.p.m. respectively were included in the diet in combination with EDB.

A report from the Hebrew University in Rehovot, Israel, shows that in a long-term feeding test started with 1-week-old calves receiving 1 mg. per kilogram of weight of EDB per day in milk, no noticeable change in growth or external appearance occurred during the first 4 weeks of treatment.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

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MARKETING FACILITIES, EQUIPMENT AND METHODS
Transportation and Facilities Research Division, AMS

Problem. Differences in varieties of the individual grain crops and in the environments of producing areas where they are conditioned and stored, together with advancing techniques in cultural and harvesting practices, require new or modified marketing facilities, equipment, and methods. Such changes are essential to efficient and economical handling, conditioning, and storing these crops and to maintaining their quality. There is a need for improved designs of facilities based on functional and structural requirements, which will expedite the movement of commodities into, within, and out of the facility. There is also a need for handling and conditioning equipment which will minimize labor and other costs. More knowledge is needed of the relative efficiency of various handling and conditioning methods so that improved or revised methods and equipment can be developed to perform necessary operations.

USDA PROGRAM

The Department has a long-term program involving both applied and basic research as well as application of known principles to the solution of problems of handling, storing, and conditioning field crops in marketing channels. Grain aeration and drying research is carried out at Athens, Ga., on wheat, corn, and oats; at Manhattan, Kans., on wheat and grain sorghum; at Lafayette, Ind., on corn; at College Station, Tex., on wheat and grain sorghum; in laboratory and pilot-scale facilities and commercial storages; in cooperation with the Agricultural Experiment Stations of Georgia, Kansas, Indiana, and Texas and with grain storage firms. Cooperative research at College Station, Tex., and Lafayette, Ind., is supplemented by research contracts, respectively, with the Airfoil Impellers Corporation and the Purdue University Station. Research on the design of grain storage structures is conducted at Washington, D. C., with field studies providing the basis for selecting capacity and type of operation. Research on the handling of grain in country elevators and terminal storages is conducted by the Manhattan, Kans., field office in cooperation with the Kansas Station. Studies of grain in CCC bins are conducted at a research bin site at Watseka, Ill.

The Federal effort devoted to research in this area totals 11.8 professional man-years; 6.8 to grain aeration and drying; 1.0 to design of grain storage structures; 1.5 to handling grain in terminal storages; 1.5 to studies of grain in CCC bins; and 1.0 to program leadership.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

Equipment Manufacturers. Several manufacturers of handling equipment for grain elevators are conducting research on the size and configuration of grain buckets used in elevator legs as well as on the discharge patterns of grain at the head of the leg. Other companies are also testing new materials for lining sections of grain spouting to increase spout life. Grain equipment manufacturers conduct studies as part of product development on new automatic sampling devices for grain, grain unloaders for box cars, and meters for indicating grain moisture. Grain dryer manufacturers depend mostly on the manufacturer of component parts to provide pieces of equipment to specification. Several dryer manufacturers depend on field studies and reports of users to suggest changes and improvements in design. Aeration equipment manufacturers generally study full scale installations. Some companies have their own facilities for testing component parts of aeration systems. Estimated annual expenditures are equivalent to approximately 12 professional man-years.

Contractors and Prefabricated Building Manufacturers. Several builders of storage facilities and manufacturers of prefabricated buildings maintain research laboratories which are used for testing components of buildings as to their suitability for use as grain storage facilities. Some manufacturers perform field tests on structures and several use a high degree of instrumentation to solve structural load problems and thus improve the quality and safety of the structures. Some builders have found it necessary to employ research engineers and designers to adapt new construction techniques and materials to economical and functional grain storage facilities. Estimated annual expenditures are equivalent to approximately 9 professional man-years.

Industry Organizations. Various industries have organized into general associations for research and promotion. These associations are conducting research on building materials such as "tilt-up"

concrete construction for buildings; multishaped, lightweight roofs; and improved weather resistant coatings for steel. Estimated annual expenditures are equivalent to approximately 15 professional man-years.

REPORT OF PROGRESS FOR USDA AND COOPERATING PROGRAMS

A. Grain Aeration and Drying

1. Aeration. Limited tests in commercial grain storages have indicated that static pressure losses in aeration ducts were being grossly underestimated. Nonuniformity in air distribution and in cooling rates have indicated the need for more precise engineering data for designing aeration systems.

Under a research contract a series of tests were conducted to determine static pressure losses in 10 different types of ducts. Some of the results of Test Series I are: (1) Perforations in ducts add approximately 25 percent to the pressure losses found in non-perforated ducts; (2) pressure losses in corrugated ducts are approximately $4\frac{1}{2}$ to 6 times greater than those in noncorrugated ducts of the same size; (3) corrugated, perforated ducts have a slightly lower loss per foot than corrugated nonperforated ducts of the same size; (4) losses in half-round ducts are approximately 25 percent greater than the losses in round ducts of the same cross section; (5) neither steel-troweled or broom-finished concrete beneath half-round ducts cause any greater pressure loss than steel bottoms; and (6) perforating of ducts having smooth walls increases the frictional resistance to air flowing within the duct; in contrast, the perforating of ducts having corrugated walls decreases the frictional resistance. A multiplier chart was developed from the Test Series I data that makes it possible to convert values for friction losses in round ducts given in published standard friction loss tables to friction losses occurring in equivalent corrugated ducts.

In Test Series II investigations were made to determine changes in static pressures occurring in various specified perforated-wall duct assemblies both with combining airflow (airflow inward through perforated wall of duct) and with dividing airflow (airflow outward through perforated wall of duct). With dividing airflow the airflow distribution was nearly uniform throughout the length of the test duct. For example, with a perforated, corrugated duct 80 feet long, the deviation from uniform flow throughout the length of the duct was only about 2 percent and with a smooth-wall perforated duct the deviation was only about 4 or 5 percent. Uniform airflow in a duct system is essential for the best performance of a grain aeration system.

At the same air velocities with dividing airflow the pressure drop or loss in the ducts, due to frictional resistance, was about $1/5$ to $1/3$ the drop measured with combining airflow. The greater pressure losses measured in tests with combined airflow are responsible for the pronounced non-uniformity of airflow occurring with this method of airflow. The data obtained in these investigations provide much needed criteria for predicting the static pressures throughout a duct associated with a given airflow; criteria that are needed in designing perforated duct systems that will distribute air uniformly along their entire length.

At College Station, Tex., laboratory tests to measure static pressure losses in the grain around aeration ducts showed a high pressure loss occurring in about the first $2\frac{1}{2}$ feet of grain surrounding the duct.

In Texas, the use of fans for reducing the temperature of the headspace (space above the grain) air and at the grain surface during the hot summer months was studied in large flat storages. Headspace air temperatures as high as 140° F. were observed in a storage with no mechanical ventilation while temperatures were from 20 to 40 degrees lower in an adjacent storage with ventilating fans providing an air change in the headspace approximately every 2 to 3 minutes. Grain temperatures near the grain surface appeared to be influenced by headspace ventilation. For example, a gradual increase in grain temperature to a depth of 36 inches below the grain surface occurred at a faster rate in the storage with no headspace ventilation.

Tests were conducted in an upright storage bin to determine the relationship of grain depth and length of storage period to an increase in the packing of the stored grain. A slight decrease in airflow was observed during a 6-month storage period which was attributed to greater packing of the grain.

A manuscript on "Operating Grain Aeration Systems in the Southwest" was completed and published.

In Georgia, a report "Operating Schedules for Aerating Systems in the Southeast" was completed and published. Aeration tests with wheat and corn were conducted in two upright storages. These tests gave satisfactory results for both summer and winter aeration.

In the summer tests of wheat two different airflow rates ($1/20$ and $1/40$ cfm per bushel) were compared at the same location. Wheat having an initial average temperature of 90° F. was stored in July. At the end of the summer test the wheat temperature in the bin aerated at $1/40$ cfm per bushel ranged between 85 and 92° F. and in the bin aerated at $1/20$ cfm per bushel between 85 and 88° F. There was no reduction in quality in either bin.

Corn having a moisture content of 14 percent and an initial average temperature of 85° F. was aerated in two bins with airflow rates of 1/9 and 1/17 cfm per bushel with thermostats and humidistats controlling the fans. With 1/9 cfm per bushel the lowest average corn temperature, 40° F., was reached after 379 hours of fan operation. With the lower airflow rate of 1/17 cfm per bushel the lowest average corn temperature, 45° F., was reached after 475 hours of fan operation, an additional 96 hours.

In one test, 24,000 bushels of wheat at 12 percent moisture were stored for 8 months (June through February) without any loss in market quality in an aerated warehouse. The fan was controlled by a thermostat and humidistat. The initial average temperature of the wheat was 91° F. Observations over the two year period indicated that airflow rates of 1/10 cfm per bushel are satisfactory for intermittent fan operation. However, airflow rates of 1/20 cfm per bushel and less are not satisfactory. This appears to be particularly true when hot spots develop within the grain mass. For example, an airflow rate of 1/17 cfm per bushel was not enough to remove hot spots using only the available fan time provided by the control settings. This agrees with previous studies and with recommendations made for intermittent fan operation.

In Kansas, studies were continued during the two year period to develop the most effective methods of operating aeration systems in commercial storages for wheat and grain sorghum in the Hard Winter Wheat Area. Tests of various methods of controlling aeration operation were conducted in large flat storages in upright storages. Observations were made of the year-round use of aeration systems for maintaining grain quality.

A report, "Grain Aeration and Turning Costs: A Comparison for a Country Elevator in the Hard Winter Wheat Area," was prepared and submitted for review. This report compares the costs of aerating and turning grain in a concrete upright country elevator with a storage capacity of 750,000 bushels. Aeration replaced turning for 500,000 bushels of grain in the storage annex. The estimated cost for the aeration elevator was 0.41 cent per bushel more than for the turn elevator. A good percentage of this additional cost was due to the costs assessed to the loss in weight caused by the water removed from the grain during aeration. Costs for controlling insects were not determined for either elevator. A report entitled "Operation of Aeration Systems in the Hard Winter Wheat Area" was completed and published.

Three different methods of controlling aeration fans--automatic, manual, and manual plus an automatic weather indicator--were studied in three flat storages having a total storage capacity of 2,350,000 bushels of wheat. At one location, automatic controls operated the fan when the outside air temperature was between 50 and 22° F. and

the relative humidity below 85 percent. Grain temperatures before winter aeration averaged 55° F. and after 636 hours of fan operation they averaged 39° F. At a second location, the fans were manually controlled but in conjunction with a weather indicator. Grain temperatures before aeration in November ranged from 26 to 102° F. After 360 hours of fan operation in November and December, the bulk of the grain was cooled to between 28 and 53° F. At a third location, manual controls were used with no effort to eliminate operation during periods of low air temperature. Grain temperatures before aeration ranged from 40 to 80° F. After 270 hours of operation during December and January the grain temperatures ranged from 13 to 58° F.

Samples of wheat were obtained in a flat storage where the wheat had been in storage for three years. These samples taken at mid-summer showed that the grain moistures 2½ feet below the surface were 1½ to 3 percent above moistures in the surface layer and slightly above those at the 5-foot level.

The need of restricting the relative humidity of the entering air was demonstrated during winter aeration where fans were operated when outside air temperatures were between 45 and 20° F. and when the relative humidity was 90 percent or less. Under these conditions the moisture of the grain in the surface foot increased from 11.4 percent to 13.4 percent which is above that considered safe for storage. Aeration was effective in establishing uniform grain temperatures. For example, temperatures ranged from 28 to 108° F. in one storage before winter aeration; after aeration, the range was only 22 to 52° F.

Grain moisture in the surface foot of grain in flat storages increased from mid-summer to mid-winter without aeration. In one building in which wheat was in the fourth year of storage, the wheat moisture in the surface foot increased from 9.5 percent to 11.3 percent during this period. By contrast, probe samples taken 2½ feet and 5 feet below the surface showed moisture changes of less than 0.1 percent during storage and aeration.

The following cooling times and average airflow rates were recorded for winter cooling at three locations: 970 hours at .027 (1/40) cfm per bushel, 378 hours at .04 (1/25) cfm per bushel, and 295 hours at 0.1 (1/10) cfm per bushel. In each case, the wheat had been in storage for more than one year. Cooling times were not directly related to the airflow rate, but were affected by uniformity of airflow and management decisions about control and operation of the systems.

In tests in upright storages the moisture removal was not uniform throughout the depth of grain during aeration and a drying zone was moved only part way through the grain depth during extended aeration

periods. The bins were filled in late June with tough wheat having a moisture content of 14 percent. One bin received 1,440 hours of fan operation at 1/20 cfm per bushel during which a drying zone--with wheat moisture below 12 percent--moved down to a depth of 15 feet and the average moisture content was reduced from 14 to 13 percent. The second bin received 2,000 hours of operation during which a drying zone moved down to a depth of 24 feet and the average moisture content was reduced from 14.5 to 12.7 percent. Wheat in one test bin graded No. 1 Hard Winter after three years of aerated storage. Germination was 86 percent and the average moisture content 11.4 percent.

Wheat which had been in aerated storage two years without turning or treating was warmed in order to establish more favorable grain temperatures for fumigation. The grain was warmed from an average temperature of 63 up to 73° F. by operating the fan when the outside air was below 73° F. and less than 90 percent relative humidity. After fumigation the grain was again cooled by aeration and remained in storage for the third year.

One study in upright storages explored the desirability of limiting fan operation to periods of low solar energy accumulation, mostly at night, from 8:00 P. M. to 8:00 A. M. High limit temperature and relative humidity settings were used. Fan operation occurred during the summer, fall, and winter, cooling the wheat from 107° F. at harvest time to an average of 39° F. after winter cooling. A moisture reduction of one-fourth percent was measured, about one-half of the normal moisture loss. The relatively low moisture loss was due in part to the low initial moisture content of 9.5 percent of the grain.

The surface moisture content of wheat was maintained above 12 percent during summer aeration by limiting fan operation to periods when outside air was below 81° F. and the relative humidity below 90 percent. In this test the surface five feet of wheat had a moisture content of 12.4 percent before aeration and 12.3 percent after aeration. In other bins aerated when the outside air was below 90° F. and 70 percent relative humidity the moisture content in the upper five feet of grain was 11.5 percent and 11.8 percent after summer aeration.

Grain sorghum having 16 percent moisture was cooled to an average temperature of 40° F. with a range of from 34 to 44° F. Automatic controls were set for fan operation with a low limit temperature of 34° F. and no high limit for temperature, but with a high limit of 70 percent for relative humidity.

Year-round operation of a combined aeration and dust control system was observed in Kansas. This system was developed during an earlier phase of this research project and installed in 12 bins of a concrete upright storage annex. Eight bins of new harvest wheat were aerated throughout the year and another bin of wheat and two bins of grain

sorghum during part of the year. During the year fan operation for aeration was approximately 1,700 hours and for dust control approximately 170 hours.

In Indiana, two year tests comparing year-round aeration and aeration limited to the fall and winter months for shelled corn in large flat storages were concluded when approximately three-fourths of the storages were unloaded during the winter of 1961-62. The corn aerated only in fall and winter had nearly twice as much damaged grain within five feet of the surface as that aerated year-round. However, the 1.6 percent damage in the corn aerated during fall and winter was well within the requirements for No. 1 grade corn. At the end of the two year storage period corn from the top five feet and from near the floor in storages aerated on a year-round basis showed from 0.3 to 1.0 percent greater loss in moisture than the corn aerated in the fall and winter only. This added loss in weight may be of equal or greater importance to the storage operator than minor increases in grain damage.

In studies made during the 1960-61 storage year, cooling was stopped earlier in the fall when the corn temperatures were still up around 50° F. There had been no noticeable heating or deterioration in the corn through the early summer months. Corn aerated through the winter and spring months had also stored without evidence of deterioration.

Grade reports on the corn shipped from buildings previously under study confirmed that corn quality was maintained by all aeration procedures tested. One lot of 250,000 bushels of corn that had been stored for three years and aerated through the fall, winter, and spring each year showed 3.4 percent grade damage when shipped. A second lot of corn aerated in the fall and early winter only, showed 4.1 percent damage. The second lot of corn showed higher damage in the top five feet of grain. The corn in two other buildings observed for one year showed an average grade damage of 2.5 percent when unloaded. The weight shrinkage from moisture loss and other causes is an important part of the total storage costs. Accurate shrinkage data are difficult to obtain until storage sites are completely emptied. The fragmentary data now available indicate that shrinkage does not increase in proportion to the number of years in storage.

Further analysis of data from the 26 aeration tests made in the laboratory at Lafayette, Ind. in 1961 showed discrepancies in estimates of heat balance and mass transfer. These appeared to be due to excessive moisture changes as measured by the apparatus in use. A series of calibration tests proved that the discrepancies were due to a progressive, but not identical, "creep" in the water-filled rubber tubes supporting the grain containers. A new series of tests are now in progress using a platform scale to measure total change in weight for comparison with the changes measured by the previous method.

Thus far these tests, at high rates of airflow, have shown that the major change in the weight of the grain occurs during the early stages of the cooling or warming process.

In the laboratory, bulk aeration tests with wheat in a 10-bushel insulated model bin were continued in 1962 and three series of tests were completed. The air temperature surrounding the bin was at the "warm" grain temperature in one series of tests and at the cooling air temperature in the others. Ambient temperature conditions had little effect on the results at aeration airflow rates of 0.5 and 0.8 cfm per bushel, but significantly affected the results in tests at 0.1 cfm per bushel.

The time required to cool wheat with an airflow rate of 0.1 cfm per bushel varies from 120 to 160 hours, according to the results of these tests. Factors affecting the cooling time are not completely evaluated but include grain moisture and temperature changes, airflow rate, and ambient temperature. The moisture change in the grain incident to the aeration process was studied with cooling air at relative humidities above, below, and equal to those in equilibrium with the cooled wheat. Results showed that a small amount of drying occurred as the cooling zone passed through the wheat, regardless of the relative humidity of the air. With the cooling air in equilibrium with the cooled grain, a 0.5 percent reduction in moisture content was recorded while cooling wheat from 80 to 50° F. The moisture reduction was 0.3 percent with the air at a relative humidity 20 percent above equilibrium, and 0.8 percent when the relative humidity was 20 percent below equilibrium. The wheat used in these tests had a moisture content of between 11.5 and 13.5 percent.

2. Drying. At Lafayette, Ind., 27 drying tests with field-shelled corn from the 1960 crop were conducted to evaluate the performance of drying equipment and to determine the effect of selected drying practices on the quality of corn for commercial uses. Comparisons were made between drying in a typical farm-type batch dryer and drying in a continuous-flow dryer commonly used at grain elevators. Shelled corn was harvested at moisture levels ranging from 20 to 30 percent and dried at air temperatures of 140, 190, and 240° F. Fuel efficiency was higher when drying corn at the higher initial moisture levels, but was not affected by the drying air temperatures used. In the continuous-flow dryer the maximum temperature of the grain during drying was about the same as the temperature of the exhaust air. In the batch dryer, the grain temperature approached that of the heated air entering the grain, resulting in somewhat higher grain temperatures than in the continuous-flow dryer. The higher drying air temperatures adversely affected the germination of the corn. For all tests using a drying temperature of 240° F. the average reduction in germination was 71 percent, at 190° F. it was 64 percent, while at 140° F., it was only 14 percent. A test to indicate the relative

starch release of the dried corn after steeping in a dilute acid bath shows consistent reduction in starch release only in those samples that were batch-dried at 240° F.

The evaluation of drying methods for high-moisture field-shelled corn was continued in the fall of 1961 with 24 field tests. Comparisons were made using three air temperatures for drying corn from two different initial moisture levels in both batch- and continuous-flow types of dryers. Two levels of airflow provided two levels of drying speed. Dryer performance and corn quality were observed for the various test conditions.

Milling tests were completed on samples from both the 1960 and 1961 drying tests. Seven different milling quality measures were evaluated statistically. Temperature was a statistically significant (0.05 level or better) treatment factor in one or both years in six of the seven measures. Although the differences among tests were small, the effect of temperature on starch yield was highly significant. The starch yield expressed in percent of the dry corn weight ranged from an average of about 60 percent for the samples dried at 240° F. to an average of about 64 percent for the control samples dried without heat. The corn dried at 190° F. had a higher average starch yield than that dried at 140 or 240° F.

Drying speed and initial corn moisture content, along with drying air temperature, were significant factors affecting the quality measures used to indicate the physical handling characteristics of dried corn. Drying with heat also had a significant effect on the susceptibility of corn to invasion by storage molds and on the grain-air moisture equilibrium relationship. More uniform grain temperatures were obtained with continuous-flow drying but at slightly lower drying efficiencies than with batch drying. Drying efficiencies were also higher when drying wetter corn and when using the lower airflow rate.

The phenomenon of "stress crack" development observed in artificially dried corn, from both field and laboratory tests, was explored in detail under laboratory conditions. The amount and rate of moisture removal as well as the drying temperature were found to affect the number of stress cracks. Under certain conditions, the number of stress cracks increased while cooling the corn or during storage immediately after drying. Drying by stages slightly reduced the number of stress cracks but not enough to be considered a practical solution to the problem. Most of the stress cracks formed during or immediately after drying through the moisture range of from 17 to 14 percent. There were fewer stress cracks in corn dried from an initial moisture content of 20 percent than in corn dried from 25 to 30 percent. There were fewer stress cracks in corn dried on the ear at 160° F. drying air temperature than in shelled corn dried at 80° F.

This difference is apparently associated with the speed of drying since shelled corn dried much faster than ear corn when exposed to the same drying conditions.

Observations on the incidence of stress cracks or fissures in the endosperm of artificially dried corn was continued in 1961. A high percentage of kernels in all artificially dried samples contained stress cracks. This limited the usefulness of stress crack counts as an index of damage from drying. However, when determinations were made on the number of kernels having a crazed, or checked appearance (two or more stress cracks intersecting) these conditions were responsive to differences in drying treatments. The number of checked kernels increases as the drying speed increases. The drying method--thin layer, batch, concurrent or counterflow movement of grain and air--also affects the checking of the kernel. The stress cracks and checking account for some but not all of the breakage in dried samples when subjected to breakage tests.

The effect of artificial drying on the air-grain moisture equilibrium was measured in corn samples from both field and laboratory drying tests during the two year period. Samples of corn having an initial moisture content of 23 percent were dried in shallow trays using air temperatures ranging from 80 to 200° F. These samples were stored at a constant humidity and temperature for periods up to seven weeks. At the end of the storage period the samples dried with air temperatures of 160 and 200° F. had a moisture content $\frac{1}{2}$ to 1 percent lower than those dried at 80° F. Two samples of the same corn were dried to 12 percent moisture, one at 80 and the other at 160° F. After 24 hours in a sealed container the relative humidity of the interseed air in corn dried at 160° F. was 7 percent higher than that in the corn dried at 80° F. Other samples dried in thin layers at air temperatures ranging from 80 to 300° F. were stored at 80° F. and 80 percent relative humidity. After three months the moisture content of the corn dried at air temperatures above 200° F. was one percent lower than that dried at 80° F. Conversely, when samples dried to about 12 percent were stored in tight containers, those samples dried at temperatures above 200° F. supported humidities at least 10 percent above those dried at 80° F. Moisture levels of corn similarly stored but from field drying tests exhibited smaller but statistically significant differences (0.05 level) among samples dried at room temperature, 140, 190, and 240° F. Results of these tests indicate that heated air drying affects the equilibrium moisture content of shelled corn, which may explain in part reports of greater difficulty in storing corn that has been dried with heated air. Tests are being continued to further substantiate the results to date.

Under a research contract with Purdue University, work was continued on the development of an automatic control system to regulate the flow of grain through a continuous-flow dryer to obtain grain of a predetermined moisture content. Investigations of moisture sensing devices, including laboratory tests, indicated that the dielectric method is the most suitable for measuring the moisture content of recently dried grain. Theoretical analysis of a hypothetical dryer column and examination of data from the AMS dryer at Purdue indicate that the dryer exhaust temperature is also a sensitive measure of the grain moisture content in a column dryer. Therefore, the dielectric method and the temperature sensing method of monitoring grain moisture content during the drying process were recommended for consideration in the development of a control system. Variations due to packing appear to be the most important deterrent in the application of the dielectric method. Periodic sampling using an automatic weighing device and a conventional system for introducing the grain into the instrument test cell may be necessary to obtain the required uniform bulk density.

A commercial type dryer control system using exhaust air temperature as a measure of moisture content was tested on the AMS dryer. These tests were not conclusive because of non-uniformities in temperature and moisture content within the dryer. Field tests of a representative model of each basic type of continuous-flow dryer was conducted to determine the scope of the problem on non-uniform drying in such dryers. These tests indicated that reasonably uniform grain moisture contents and temperatures can be obtained in commercial dryers of this type. Technical reports were prepared and submitted by the contractor to satisfy the requirements of the research contract.

A model of a column-type, continuous-flow dryer was constructed and tested. This dryer was designed to provide information for computer simulation of the drying process and as a drying plant for the preliminary testing of the prototype control system. Airflow rates of 75 cfm per bushel and temperatures above 250° F., with controlled relative humidity, can be obtained with this system.

Tests were run to determine the effects on drying resulting from changes in initial grain moisture content, airflow rates, drying air temperature, and relative humidity. Changes in relative humidity within the range considered had no significant effect on the drying process. The grain moisture content as a function of temperature and airflow rate checked very well with the relationship given by the drying equation. Some error was encountered in the use of the equation when the initial moisture content was varied. The use of exhaust air temperature as a measure of moisture content did not look favorable based on the results of the test.

Tests with the laboratory dryer provided the information necessary for simulating the drying process and control system on the electric computer. Computer simulation will be valuable in determining the proper adjustment of the dryer controller. The prototype automatic control system was installed on the laboratory dryer and tested. The original duration-adjusting-type controller used in the prototype had several shortcomings, the most outstanding being the inefficient range of adjustment and a shift in cycle time or period when adjustments were made. This controller was replaced by one having a wider range of reset adjustment plus a rate control mode.

The optimum location of a single moisture sensing point has been determined to be at the grain discharge from the heater section. Multiple sensing points would greatly increase the cost and complexity of the control system and therefore this approach does not appear feasible at the present. The computer simulation will aid in obtaining a more complete evaluation of the use of multiple sensing points. Technical reports have been submitted by the contractor to satisfy the requirements of the research contract.

B. Design of Grain Storage Structures

Field studies made in 1961 showed that current construction costs of modern upright concrete elevators (200,000- to 500,000-bushel capacity) in the Central Great Plains averaged about \$0.70 per bushel. These elevators receive annually a volume of grain equal to 1.1 times their average capacity. Receiving capacities ranged from 5,000 to 8,000 bushels per hour per elevator. In comparison, costs for modern flat storage facilities, common in the grain sorghum producing areas of Texas, averaged about \$0.31 per bushel. However, these storages could only receive about 2,500 bushels per hour per storage, and the volume of grain received annually averaged only 70 percent of the storage capacity. Modern elevators in the Corn Belt were similar to those in the Great Plains, except that they receive annually approximately four times their storage capacity.

Tests conducted on large concrete upright commercial grain storages showed that the strength of the concrete used varied considerably with the contractor building the structure. All storages tested were designed on the basis of 3,000 psi (pounds per square inch) concrete. However, the average strength of concrete in storages built by one contractor averaged 4,000 psi while that used by another contractor averaged only 2,800 psi. The strength of the concrete also varied considerably throughout any one structure. For example, the strength of one typical storage varied from 2,300 psi to 3,000 psi at different points on the wall at the same height but at different locations around the perimeter. There was even more variation in the strength of the concrete at different heights. For example, the strength of concrete in the walls of one structure varied with the height from

1,800 psi to 5,400 psi. These tests indicate a need for better quality control in the construction of concrete grain storages.

The queuing theory, an accepted technique of operations research, is being used to develop improved layouts and designs of truck unloading facilities which will reduce waiting time and costs at the elevator during harvest. Field studies were conducted during both the grain sorghum and wheat harvests in Kansas to collect data on truck arrival and service time patterns.

At the elevators studied, about 22 percent of the total number of trucks arriving during the harvest season arrived in one day and about 10 percent of the total trucks arriving in a day arrived during one hour, usually between 4:00 and 5:00 P. M. During any one hour, truck arrivals follow a Poisson distribution--a statistical pattern where arrivals occur at random times but where the expected number of arrivals is approximately proportional to the length of the time intervals--thus, when truck arrivals averaged 36 trucks per hour, 3 trucks would be expected in a 5-minute period. The service time patterns for weighing and unloading trucks follow closely an Erlang distribution--a statistical distribution function often used in the theoretical waiting line analysis.

C. Handling Grain in Country Elevators and Terminal Storages

At College Station, Tex., work during 1961 was confined to the preparation of a manuscript on "Receiving Grain Sorghum at Country Elevators in the Southwest" which has been published.

At Manhattan, Kans., a report, "Receiving Grain from Trucks at Country Elevators in the Hard Winter Wheat Area," was completed and submitted for publication. The report includes results of studies of observed and improved methods for (1) truck scale operation, (2) unloading trucks, and (3) moving grain from drive pit to headhouse. A good layout of equipment and coordinated methods at the truck scale are important to rapid and efficient weighing of farm trucks during harvest. Using the methods observed at country elevators, a 3-man crew at the drive pit unloaded trucks at a rate of 5,850 bushels per hour with a direct labor and equipment cost of 18.6 cents a truck. An improved method using a 3-man crew increased the receiving rate to 7,400 bushels per hour while reducing the direct labor and equipment cost to 16.1 cents a truck. Recommendations presented will be useful to elevator managers in selecting improved methods, equipment, and equipment layout for receiving farm trucks at country elevators.

Another report on a "Full Bin Indicator for Grain Elevators" was completed and published. This report discusses an inexpensive, portable indicator for indicating when bins in grain elevators are full. This report has been given wide distribution in grain trade magazines.

and it is anticipated that this device will be widely used by country elevator operators with a saving in time, cost, and manpower. By sounding a warning when a bin of grain is full, bin overflows can be prevented in which grain piles up at the rate of 100 bushels per minute. Also the time required for measuring a bin during the filling operation can be appreciably reduced.

Field studies of grain shipping operations at country elevators have been completed and a report prepared entitled "Shipping Grain from Country Elevators in the Hard Winter Wheat Area." This report compares labor and equipment costs for shipping grain from elevators of different sizes using 2-man crews. Comparative labor and equipment costs were as follows: 200,000-bushel elevator--0.51 cent per bushel; 750,000-bushel elevator--0.48 cent per bushel; and 1,500,000-bushel elevator--0.46 cent per bushel. The elapsed time to load a box car varied from 52 minutes when using a car puller, a bifurcated spout with hand winch, and a 25-bushel capacity automatic scale, to 83.4 minutes when using a hand operated car mover, a single flexspout with wire stretchers, and a 10-bushel capacity automatic scale.

Field studies of receiving grain by rail car at terminal elevators were initiated in 1961 and completed in 1962. In 1961 time studies of unloading rail cars at terminals were obtained for (1) power shovels with 4-man and 6-man crews; and (2) car dumpers of two different makes. The average time to unload 796 cars with a 4-man crew using power shovels was 15.4 minutes per car at a labor cost of about 6½ cents per bushel. Additional studies during 1962 included unloading cars with a paddle conveyor, an "augermobile" and "Kar-Flo" (shaker), and one make of car dumper. The paddle conveyor and the "augermobile" each left approximately 6 inches of grain in the bottom of the box car which was then removed by use of power shovels. Handling reports from one terminal elevator for a two month period showed the elapsed time for unloading cars with one make of car dumper was 8 minutes, and for loading a car, 4½ minutes.

Summaries of daily grain handling reports were compiled for two terminal elevators for two years. One terminal, equipped for unloading box cars with power shovels and with elevating legs moving 15,000 bushels per hour, moved an average of 2,059,000 bushels each month. The average electric power cost for one year was 2.29 cents per kilowatt hour. Another terminal, equipped for unloading with a car dumper and with legs moving 30,000 bushels per hour, moved an average of 4,657,000 bushels each month. The average electric power cost was 1.85 cents per kilowatt hour. Such information will be particularly useful in evaluating equipment usage and normal handling capacities at terminal elevators.

A comparative test of wear resistance of various liner materials for grain spouts is underway. The quantity of grain handled before the material is worn out is being recorded at an operating grain elevator.

A comprehensive study of grain cooling during turning operations and extended periods of storage has been underway during a two year period. Grain temperatures were recorded during storage, including temperature changes while the grain was turned three times--summer, fall, and winter. The maximum variation in temperature of grain against the outside wall was 7° F. while the outside air temperature varied 23° F. The maximum grain temperature lagged the maximum outside air temperature by about 4 hours in the afternoon and the lag for the minimum temperature in the morning was about 3 hours. There was little or no daily fluctuation in temperature in grain 6 inches in from the sidewalls.

In another test a bin was filled at harvest time with wheat with an average temperature of 92° F. The wheat was turned three times--summer, late fall, and late winter--after which the average grain temperature was 56° F. Average changes during the eight months of storage included: Grain moisture reduced from 11.6 to 11.4 percent, test weight increased from 61.2 pounds per bushel to 62.4 pounds, and germination reduced from 96 percent to 92 percent. The official grade was No. 1 Yellow Hard Winter Wheat throughout the storage period. Following the late winter turn, this lot of wheat was placed in static storage to remain for one year unless grain temperature or other changes indicate a need to turn.

In 1962, observations were made of different methods used for receiving, sampling, and storing wheat at elevators where sedimentation values are used as a premium factor. Most wheat was received and stored at country elevators without regard to quality determinations. Wheat samples obtained from a number of storages had sedimentation values ranging from 24 to 67 (premium range is 40 to 65). Storage treatments planned by different elevator operators include static storage, aeration, turning twice annually, and turning as frequently as once each month.

D. Studies of Grain in CCC Bins

Studies of maintaining the quality of shelled corn by using standard USDA aeration systems in 3,250-bushel bins are on a continuing year-to year-basis. Corn from the 1955 crop year was stored in September 1956 with an initial moisture content of 14 percent. Continuous aeration over a 6-year period has reduced the moisture content to 12.5 percent. During the same period, total damage increased about 7 percentage points. A continuously-operated fan caused a slight wetting of the surface corn during the winter months but this corn dried during the spring and summer. Since airflow was downward

through the corn, the drying action at the surface wetted areas of corn deeper in the bin. Various methods of fan control are being studied to lessen this moisture increase. In one test, fans operated as exhausters until December, stopped until February, then operated until September moved the excess moisture out of or redistributed it in the corn mass. In a variation of this test, fans operated as exhausters until January instead of December.

Samples drawn from the upper eight feet of shelled corn in these test bins show an average increase in total damage of less than one percentage point after two years of storage. Increases in total damage in comparable test bins with the fan operating continuously in the exhaust position were slightly less than two percentage points. Corn stored in the fall of 1961 at a different moisture showed about the same ratio of increases in total damage after one year of storage. There was no significant advantage in operating the fans as exhausters until January instead of December.

Shelled corn stored in two flat storages was aerated at an airflow rate of 1/8 cfm per bushel with the airflow direction reversed in one of the two buildings. This corn was placed in storage in the fall of 1960 with a moisture content of about 14.5 percent. In this study the fans were controlled by a time clock which permitted four hours of fan operation daily between September 1 and June 1 with a different four hour period from September to December, December to March, and from March to June. After 1½ years, data from the above tests indicate that with the fan operating as a blower the corn has more uniform moisture and temperature patterns, less increase in total damage, and a higher germination.

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IV. ECONOMIC RESEARCH

ECONOMICS OF MARKETING Marketing Economics Division, ERS

Problem. Most agricultural processing industries are experiencing rapid and drastic changes in their market organization and practices. These changes are affecting both farmers and consumers. Research is needed to keep abreast of such changes and to indicate their probable consequences. There have been substantial advances in recent years in increasing efficiency and reducing costs through adoption of new technology in producing, assembling, processing and distributing farm products. However, for producers and marketing firms to remain competitive, additional information is needed on margins, costs, economies of scale and efficiencies possible in the marketing of farm products.

USDA PROGRAM

The Department has a continuing long-term program of economic research relating to grain including study of the market potentials of new products and new uses; marketing costs, margins, and efficiency analyses; and marketing structure, practices, and competition. The research involves economists and personnel with dual economic and technical training and is carried out at Washington, D. C., and field offices in Albany, California; and Peoria, Illinois, and in cooperation with State Agricultural Experiment Stations in a number of States. The grain phases of the research involve 10.8 Federal professional man-years of which 6.4 are studying market potentials, 2.5 margins, costs and efficiency; and 1.9 structure, practices and competition.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

Only limited resources as phases of broader projects are being devoted to market potential studies of grain products by State Experiment Stations. More emphasis is placed on grain costs and efficiency research and on the impacts of changing conditions on grain marketing institutions and the structure of grain markets.

Industry and other organizations also conduct or sponsor research on new products and new uses for grain. The amount of research conducted by private firms on marketing margins, costs, and efficiency is not known, but it probably is small.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

Market Potential Studies

Frozen Bakery Products. A survey of 500 bakers has been carried out to

collect information on bakery operations and the probable role of freezing as a first step in appraising the feasibility of adopting this change in distribution method. These data should show how freezing is currently being used by bakers, trends in its uses and applications and the effect that freezing baked goods has on operating costs. Work is underway to analyze the data collected and prepare a publication for use in decision making as to the further role of freezing in bakery product production and distribution.

Bulgur. A market test of canned cooked wheat (Redi-Wheat), developed by Western Utilization Research and Development Division, ARS, was conducted in cooperation with the Kansas Wheat Commission and Western Utilization in Wichita, Kansas. The data have been analyzed and a report prepared. During the market test, Redi-Wheat outsold 57 established foods which might be used in similar ways. Six months later sales leveled off lower than anticipated but the product still outsold 6 of 10 of the 57 similar products. Redi-Wheat is being commercially distributed in Kansas, Colorado, and Missouri. Efforts are being made by the Kansas Wheat Commission to encourage national distribution.

Grain for Adhesives. Research is nearing completion to appraise the technological and economic factors affecting use of adhesives to relate these to present and potential markets for grains in adhesive manufacture, and to provide guides for further research based on more precise knowledge of end-use requirements. Adhesives have high unit value and raw materials such as corn and wheat need to keep pace with expanded use of synthetics in adhesives.

Starch in Industrial Uses. Expansion of industrial uses for grains is essentially a problem of finding new uses or expanding existing uses for starch or for products in which starch or a starch derivative is a major component. As a first step to identify new market possibilities and to evaluate technical and economic factors affecting potential uses for starch, a contract study has been initiated to carry out a patent search and a bibliography review of starch research for the period January 1, 1951, to June 30, 1962. The contractor is making a critical evaluation of marketing ideas and products exposed in the literature or elsewhere as guides to new industrial use development for grains.

Costs, Margins and Efficiency Studies

Bread prices and marketing margins continue to rise. By 1961, the average retail price of a 1-pound loaf of bread was 20.9 cents, up 0.6 cent from 1960 and 7.4 cents above the 1947-49 average. The farm share of the retail price in 1961 was only 2.9 cents per loaf. Although rising costs of flour milling, transportation, baking and retailing were found to contribute to these increases in costs and margins, the major causal factor has been sharply rising costs of

distribution by baker-wholesalers. Research to find more efficient methods of bread distribution is underway. Retail prices of rolled oats and corn flakes also were at record high levels in 1961 and 55 percent above the 1947-49 average. Rising costs of producing, packaging, and distributing breakfast cereal products are the primary causes of these increases. Although the breakfast cereal manufacturing industry is highly concentrated, this does not appear to be an important factor in the rising prices and marketing margins.

Market Structure, Practices and Competition

Grain marketing channels changed in many ways during the 20 years, 1939-59, in the marketing of wheat, corn, oats, barley, sorghum grain, and rye. Decentralization of marketing operations was a major trend during this period. Although off-farm sales of feed grains increased from 40 million tons in 1939 to 96 million tons in 1959, receipts at 14 major terminal markets remained almost unchanged. Thus, these receipts as a percentage of off-farm sales fell from 82 percent to 43 percent. In addition to the trend toward bypassing terminal markets more and more grain is moving from farms to subterminal elevators located at interior points. In 1959, fewer and larger country elevators handled a much larger annual volume of grain than in 1939 and many of the interior elevators assumed many of the functions of terminal elevators. Export markets have become increasingly important in recent years as an outlet for U. S. grain and changes in transportation facilities and methods, including the St. Lawrence Seaway, have influenced grain movements and trade channels. More than three times as much grain was processed and manufactured into prepared animal feeds in 1959 as in 1939. Farmers in 1959 sold 38 percent of the feed grains they produced and repurchased 51 percent of their off-farm sales in the form of mixed feeds.

Findings indicate that commercial storage more than doubled from 1955 to 1960 due to increased production, increase in CCC carry-over stocks, and movement of out-State stocks to storage along export routes. Construction material shifted from concrete to steel. Type of construction from upright to flat due to smaller initial investment costs and ease of maintaining market value. Sorghum receipts are principally by truck, but shipments are by rail. Aeration has increased rapidly and fumigation is universal. On-farm storage also increased. About one-half of production is sold at harvest, principally to elevators. Sales to truckers are unimportant. More than one-third is stored in commercial elevators and less than one-fifth on farm, usually in flat structures. Eighty percent of elevator stored sorghums and thirty-eight percent of farm stored sorghums were under CCC loans. Most farm storage problems come from high moisture and insects. Quality maintenance practices vary widely in methods and effectiveness.

Study investigates the feasibility of providing a hedge in future contracts for high protein premiums for spring wheat. Such a hedge is not now

possible, but many buyers and sellers of wheat wish that it were. Although technically it might be feasible to provide a hedge against fluctuations in the high protein premiums, this would not be practical. If a future contract would provide protection against the fluctuation in high protein premiums for spring wheat, speculators, who usually carry a substantial volume would be discouraged from participating in future markets. The already thin future markets in spring wheat would become even thinner.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

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IMPROVING MARKETING OPERATIONS THROUGH
RESEARCH IN FARMERS' COOPERATIVES
Farmer Cooperative Service

Problem: Farmers, in marketing their production, face a revolutionary change in terms of market organization and marketing practices. The growth of supermarkets and volume distribution dominate the retailing of agricultural products. To serve this type of market requires large quantities, uniformly good quality and frequent delivery. The small farmer, working alone or a cooperative or local firm of limited size often cannot meet these specifications. Cooperatives must find ways to consolidate volume, either through internal growth, merger, acquisition or federation to help them meet the needs of mass merchandising.

The increased costs in marketing farm products call for more efficient organizations. Ways must be found to increase efficiency through improved operations, better organization, and more mechanization. This is particularly important for both cooperative members and other farmers, since the principle of services at cost provides an effective means for limiting wide marketing margins.

USDA PROGRAM

The Department conducts a continuing long-range program of basic and applied research and technical assistance on problems of marketing farm products cooperatively. The basic purpose of this work is to help farmers, through their cooperatives, to increase net returns, to improve quality, and to expand markets for their products. Studies are made on problems of organization, operations and the role of cooperatives in marketing farm products. While most of the research is done directly with cooperatives, the results are generally of benefit to other marketing firms.

The work is centered in Washington, D. C. Many of the studies, however, are conducted in cooperation with various State Experiment Stations, Extension Services, the Departments of Agriculture.

The number of professional Federal man-years devoted to grain is 2.3.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Stations are devoting 0.7 man-years to work on grains in Illinois to study the factors responsible for financial success of cooperative grain elevators and the potential market for corn in the Southeastern States, and in Oklahoma to make an analysis of the level and variation in costs of the various inputs in cooperative grain elevators.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

1. Coordination of marketing. A case study is underway on the feasibility and possibility of combining two local cooperative elevator associations in Iowa. Information is being provided to a number of regional cooperatives interested in establishing river houses and export elevators. Analysis of grain marketing problems in the South is being carried on in cooperation with the Agricultural Experiment Stations in the area.
2. Cost and efficiency of operations. Analysis of data has continued on the study of the cost, volume, size relationships of new country elevators in the Spring Wheat Area (North Dakota). A report will be published next year. Data on the economics of flat storage in Kansas, in cooperation with Kansas State University, are being analyzed and a report will be issued next year. Particularly important are data on weight loss and quality deterioration. In cooperation with Economic Research Service, a study of the economics of grain bank operation is underway. The work is being done by Purdue University under contract and preliminary report should be published next year.
3. Improving operating methods. The problem used in accounting schools for cooperative elevator bookkeepers has been revised and used in six schools in the last two years. An advanced problem has been designed and used in one school. The annual analysis of the financial status and operation of the regional grain cooperatives was continued.
4. Loss and damage to grain in transit. Farmers and their marketing agencies incur millions of dollars of loss each year due to damage and loss associated with the movement of agricultural products from producing areas through the marketing process to final destinations. Such losses must be borne, in part, by one or more segments of the industry. Detailed data have been collected on 10,000 cars of grain covering a 2-1/2-year period from 75 country and 6 terminal elevators regarding loss and damage in transit. Data on loss records and equipment are also being assembled on barge shipments of grain from eight grain elevators located on the inland waterways.

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ECONOMIC AND STATISTICAL ANALYSIS
Economics and Statistical Analysis Div., ERS

Problem: Adequate and accurate information is needed on supplies, production and consumption of farm products, and the effects these and other factors have on the prices of agricultural commodities. Such information is needed in planning operations for the producers, processors and distributors and also benefits the consumer in selecting his purchases. Similarly accurate quantitative knowledge of the interrelationships among prices, production and consumption of farm products are needed by Congress and the Administrators of farm programs to effectively evaluate current and future price support and production control programs.

Due to the instability of the prices he receives, the farmer stands in special need of accurate appraisals of his economic prospects if he is to plan and carry out his production and marketing activities in an efficient and profitable way. The farmer needs to be provided with economic facts and interpretations comparable to those available to business and industry, through a continuous flow of current outlook intelligence and the development of longer range projections of the economic prospects for the principal agricultural commodities.

USDA PROGRAM

The Department has a continuing program of basic research concerning the factors affecting prices, supply, and consumption of principal agricultural commodities and the analyses of the situation and outlook for selected commodities. The Federal professional man-years involved for grain are 4.5 annually.

Work on the supply and demand for feed grains involves 0.5 professional Federal man-years located in Washington, D. C. The emphasis in this area is on development of data and statistical analyses which can be integrated into the larger analysis of the feed-livestock economy. The study includes statistical measures of the factors that affect the supply and demand for feed grains. Special emphasis is being given to the interrelationships of prices and the substitution possibilities in the utilization of feed grains among the different kinds of livestock. Analyses are also being developed which will measure the influence of the factors affecting the production and supply of feed grains. Special emphasis will be given to the effect of changes in the price of one feed on the production of not only that feed grain but also other feed grains competing for the same farm resources.

Work on grain situation and outlook is located in Washington, D. C., and involves 4.0 professional Federal man-years, divided equally between feed and food grains.

The outlook and situation program for feed provides a continuing appraisal of the current and prospective economic situation for feed grains, by-product feeds and forages. These appraisals are published 6 times a year in the Feed Situation and quarterly in the Demand and Price Situation. An appraisal of the food use of feed grains is prepared quarterly for the National Food Situation. A comprehensive analysis of the feed situation is presented at the Annual Outlook Conference. Outlook appraisals also are presented at regional outlook meetings and at meetings of farm organizations and various agricultural industry groups. Special analyses are prepared of the probable effect of current and proposed longer term feed grain programs on prices, supply, utilization and carryover of feed grains. Special attention is being given to the effect of such programs on the feed grain production-utilization balance. The failure of utilization to keep pace with production has been a major agricultural problem and will continue to require special attention in the years ahead. Basic statistical series covering feed grains, high-protein and other byproduct feeds, commercially prepared livestock feeds, and forages are maintained, improved and published for use in statistical and economic analysis. A Statistical Handbook, Grain and Feed Statistics, is published annually.

The outlook and situation program provides a continuing appraisal of the current and prospective economic situation of food grains, which includes wheat, rye, rice, and their products. The appraisals are published 5 times a year in the Wheat Situation, annually in the Rice Situation, and quarterly in the Demand and Price Situation and the National Food Situation. Outlook appraisals are presented at the Annual Outlook Conference, at meetings of farm organizations and to agricultural industry groups. Special analyses are prepared from time to time on the probable effect of proposed programs on the price, supply and consumption of food grains. Basic statistical series are maintained and improved and are published annually in Grain and Feed Statistics.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

All state experiment stations are engaged in price research to fulfill the needs of farmers, handlers, and processors for information necessary for intelligent production and marketing decisions. The USDA provides much of the basic and background information but more geographic specifics and more detailed analysis is often requested of the experiment stations.

A few private colleges and organizations are engaged in price research and may give attention to agricultural products from time to time.

A substantial number of private organizations--including manufacturers of food and fiber products, private commodity analysis, banks and investment houses--are engaged in commodity outlook work similar to that carried on by USDA. This work, however, frequently relates to shorter time periods than those covered by the Department's outlook appraisals; is predominately for private use; and not available to the public.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

Supply Demand and Price. An article was published in the September 1962 issue of the Feed Situation which reported findings from several analyses that measured the effects of selected factors on the total quantity of corn and of all feed grains fed to livestock. Of the factors considered, those found to be most important in influencing the consumption of corn were the price of corn, number of grain consuming animal units fed, the relation of price of livestock and products to the price of corn, and time trend. Results from the statistical analysis indicated that a 10-percent change in corn prices resulted in a 3.4-percent change in the opposite direction in corn consumed by livestock. In the case of consumption of total feed grains, it was found that a 10-percent drop (or increase) in the price of feed grains resulted in around 3-percent increase (or drop) in consumption.

Situation and Outlook. Feed grain supplies declined 8 percent from 1960-61 to 1962-63, following nearly a decade of steadily increasing supplies. The smaller supplies resulted largely from a reduction in feed grain acreage through participation by farmers in the Government Feed Grain Program. Feed grain production in 1961 was reduced below utilization for the first time in 10 years and carryover stocks into 1962-63 were reduced to about 73 million tons, 12 million below carryover into 1961-62. Both domestic use and exports of feed grains reached new record-high levels in 1961-62, reflecting a good demand in this country and abroad. Demand for feed grains is expected to continue strong and the 1962 crop is expected to again fall below consumption, resulting in a further reduction in carryover stocks at the close of the 1962-63 marketing year.

During the past year, special attention has been given to factors affecting the consumption of feed grains and to the problem of reducing surplus feed grain stocks. This has included analyzing the effects of various types of Government programs on feed grain production, prices, utilization, and carryover. An analysis was made of the effect of Government programs on exports of feed grains as part of a special study, Analysis of Grain Export Programs, prepared by a technical committee of the Department. The annual Statistical Handbook, Grain and Feed Statistics, was published in June 1962. This issue carried long-term series and was expanded to include additional data on price support programs, and foreign trade.

Analyses of feed grain consumption revealed that the low price of feed grains in relation to the cost of other items going into livestock production, as well as in relation to livestock prices, has been important in influencing feed consumption in recent years. The moderate increase in the number of grain consuming livestock also contributed to increased feed requirements. A study on sales of feed grains by farmers revealed that farmers now sell about 45 percent of the feed grains they produce, compared with only about 25 percent in the late 1930's. Much of the increase in feed grain production during this period has been sold. In 1962-63, the supply of wheat declines, reversing the trend of recent years. The stocks on hand at the beginning of the current year were sharply reduced by the record heavy exports in 1961-62, and the current crop is substantially smaller as a result of the special 1962 wheat program. With total disappearance expected to be greater than the 1962 crop, stocks would again be reduced in 1963.

Prices in 1962-63 are starting from a high level and may therefore show little seasonal advance. With the tight supply situation, they are likely to average above the effective price support level for the entire year.

During the last 18 months, a number of articles have been published on the consumption of wheat and other cereal food products. These appeared in the Wheat Situation and the National Food Situation, covering bread, macaroni foods, breakfast cereals and trends in consumption of all cereal foods. Since the end of World War II, per capita consumption of flour and cereal products has declined 15 percent, a continuation of the downtrend that has been underway since the turn of the century. Wheat accounts for about 80 percent of the flour and cereal products consumed as food; corn, about 10 percent; and oats, barley, rice, rye and buckwheat, the remaining 10 percent. Most of the decline has been in wheat flour or cornmeal. Other food uses of these grains are about unchanged.

Analysis of the decline in bread consumption indicates that most of the decline has been in home baked bread, with very little decline in commercial bread. The recent level of commercial bread consumption appears to be fairly well established, unless there is a change in the pattern of consumer tastes or in the low price elasticity of bread.

Among the conclusions in the export program study was that prices and hence farm income would tend to be higher under either a PIK or a cash subsidy export program than under a program where exports come largely from CCC stocks. This is because the PIK or cash subsidy program encourages the trade to bid for export supplies in the open market, enhancing open market demand. In contrast, sales from CCC stocks for export tend to depress prices, since the export outlet is denied to free-market supplies, the excess of which must ultimately find its way into the hands of CCC under the price-support program.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

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CONSUMER PREFERENCE AND QUALITY DISCRIMINATION -
HOUSEHOLD & INDUSTRIAL
Standards & Research Division, SRS

Problem. With the increasing complexity of marketing channels and methods, it has become almost impossible for the consumer to express to producers either his pleasure or displeasure with available merchandise. In order to market agricultural products more efficiently, we need to understand existing household, institutional, and industrial markets and the reasons behind consumers' decisions to purchase or not to purchase. Information is needed on preferences, levels of information or misinformation, and satisfactions or dislikes of both present and potential consumers. We also need to know consumer attitudes toward the old and new product forms of agricultural commodities and their competitors, and probable trends in the consumption of farm products. We need to know the relationship between agricultural and nonagricultural products and the relationship of one agricultural commodity to another in consumers' patterns of use. Producer and industry groups and marketing agencies consider this information essential in planning programs to maintain and expand markets for agricultural commodities which, in turn, increase returns to growers.

USDA PROGRAM

The Special Surveys Branch of the Standards and Research Division conducts applied research on representative samples of industrial, institutional, or household consumers and potential consumers, in local, regional, or national marketing areas. Such research may be conducted to determine: Attitudes, preferences, buying practices, and use habits with respect to various agricultural commodities and their specific attributes; the role of competitive products, and acceptance of new or improved products.

The Special Surveys Branch also conducts laboratory and field experiments in sensory discrimination of different qualities of a product. These studies ordinarily relate discrimination to preferences and attitudes as they influence purchases in order to assess the standards of quality, packaging, etc., which are needed to satisfy consumer demands.

In addition to surveys of consumer preferences and discrimination, the Special Surveys Branch also provides consultants and conducts special studies, upon request, for other agencies within the Department of Agriculture or within the Federal Government, when survey methods can be usefully applied to the evaluation of programs, services, or regulatory procedures of interest to the requesting agencies.

The work of the Branch is carried out in cooperation with other Federal governmental agencies, divisions within the Department of Agriculture, State Experiment Stations, Departments of Agriculture, and land grant colleges, agricultural producer, processor, and distributor groups. Closely supervised contracts with private research firms are used for nationwide surveys; studies in selected areas are usually conducted by the Washington staff, with the assistance of locally recruited personnel.

The Branch maintains all of its research scientists, who are trained in social psychology and other social sciences, in Washington, D. C., which is headquarters for all of the survey work whether it is conducted under contract or directly by the Branch.

The Federal scientific effort devoted to research on consumer preference for grain and grain products was 0.2 professional man-years.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Agricultural Experiment Stations. The Stations do not report any of their work under this heading. However, they do have a considerable program in the area of consumer buying and use practices and motivation and decision making. This includes some research in preference and quality discrimination.

Industry and Other Organizations conduct research in this area, but the research done by individual firms and organizations is almost without exception for their exclusive internal use. There are very few instances in which the findings are made public or made available for government reference. In addition to the research actually initiated and paid for directly by industry, a substantial amount is undertaken in their behalf as part of the service provided by their advertising agencies.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

Per capita declines in the human consumption of wheat have lead to a search for new markets and new forms in an effort to expand consumption. A new canned form of cooked whole wheat developed by the U. S. Department of Agriculture's Western Utilization Research Laboratory was introduced in a market test in Wichita, Kansas, in 1961. Two varieties were offered, a plain cooked wheat, and one flavored with chicken. Results of the market test, which was conducted in cooperation with Economic Research Service and the Kansas Wheat Commission, indicated that the test product could compete favorably with various prepared items such as canned or dry rice or spaghetti dinners. About 18 percent of the households in the study area had purchased the test product by the end of the two-month market test period. Although users appeared well satisfied with the product, a followup, made two months after the end of the original survey, indicated that the level of purchases during the two-month period had

declined to about 9 percent of the households, of whom about half were repeat purchasers from the original survey. A related survey of restaurant use of the test product indicated that about one-sixth of the area restaurants had used it. Its use was confined primarily to the larger restaurants or cafeterias. While the number of establishments reporting use was too small to permit detailed evaluation, there appeared to be general satisfaction with the test product especially when used as a filler or meat extender. A report on this work is being prepared for publication.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Umstott, H. D. 1961. Preliminary results of a market test of bulgur (redi-wheat). Paper presented to a meeting of the Kansas Wheat Commission, September 1961.

IMPROVEMENT OF CROP ESTIMATING PROCEDURES
Standards and Research Division, SRS

Problem. The Statistical Reporting Service produces a large number of current statistics pertaining to agriculture. Because of limited resources, statistical methods were devised with a view of producing the most information for the least cost. These methods are subjective in nature and are based largely upon self-selected samples from voluntary crop reporters, who fill out and return mailed questionnaires. The information is generally collected in the form of relatives such as acres this year compared to last, and crop condition as a percentage of full crop. Persistent bias is removed by charting the census or other check data are generally projected to form current estimates. Estimates based on these sample methods have proved relatively satisfactory over the years. However, in seasons when changes are unusually large the changes may not be fully reflected in the appraisals and reports of the respondents to mailed questionnaires. In situations like this, when accuracy is needed most, the estimates may lack the required precision. Then, when the estimates are translated into available supplies for the different commodities, price inequities may occur and, as a result, producers or the processors of agricultural commodities may suffer serious financial loss.

With the development of modern statistics, new methods based upon probability sampling have been developed. Although surveys based upon probability sampling are more expensive to conduct than the traditional self-selecting mailed survey, these new methods offer a means of increasing the precision and reliability of the estimates. A properly designed well-conducted sample survey can produce unbiased estimates which have the desired levels of precision and reliability. Because of the need by the agricultural economy for high quality statistics, it is mandatory that the statistical theory and methods be developed and adapted to the needs of SRS. Some of the new procedures have already been introduced but there is an urgent need for a continuing research to devise efficient survey methods so as to make possible continuing improvement in the quality of SRS statistics.

USDA PROGRAM

The Department conducts a program of applied research designed to strengthen and improve the methodology used in collecting agricultural statistics. The principal disciplines involved are mathematics, statistics and probability, but other disciplines

relating to a particular problem are brought to bear as required. Examples of these are plant physiology, psychology, cartography and photogrammetry. The current program related to grain consists of 2.0 professional Federal man-years per year working on methods for forecasting and estimating the yields of important grain crops. Work under this program is done in Washington, D. C., and in SRS field offices located in the States concerned.

The studies on forecasting sorghum yields are being conducted under a cooperative agreement with Iowa State University in Ames, Iowa.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

Because of the orientation and specialized nature of research in this area, research activities outside the government are limited. A number of industries serving agriculture collect information for their use, but this is usually based upon field men's observations and there is no program of related research being conducted. A number of State agencies and a few industry groups cooperate with the Department by supplementing Department resources in order to extend scope or frequency of reports so there is little need for research in crop estimating methods outside the Department which is independent of the Department's program.

REPORT OF PROGRESS FOR USDA AND COOPERATIVE PROGRAMS

A. Objective Measurement of Yields

Grain Sorghum. Methods of measuring and forecasting yield and production sorghum are being studied by Iowa State University located at Ames, Iowa. Relationships have been discovered which can be used to predict the number of sorghum heads, but more work is needed on the forecasting of weight of grain per head.

Corn. Yield studies were conducted during the 1961 crop season in plots in about 440 fields in Michigan, South Dakota and Virginia. Forecasting procedures are being developed for these States similar to those growing out of earlier studies completed in other States. Considerable progress was made in sharpening up certain of the definitions involved in the concept of an "ear of corn." Shortly after ears have been silked and before they have reached their maximum size, there has been inconsistencies in the way field samplers have defined ears of corn with grain. For counting purposes, modification was made in the criteria for classifying ears for the 1962 surveys. To date the counts indicate that this change has improved the results when compared to other survey counts. Work in refining the model for forecasting weight of grain per ear has continued. The parameters used in the models have shown continued improvement as more experience is gained in different crop years and under different crop conditions. Additional precision is also being obtained in an

alternative grain weight per ear model through the data available from the sample ears submitted to a central laboratory. The dry weight of immature grain, used in conjunction with moisture content to determine the stage of development, has provided a means of forecasting grain weight under condition of substantial year-to-year change. Studies to indicate the potential damage from frost which are based on maturity considerations on August 1 and September 1 are being continued in connection with the laboratory phase of the work. These studies indicate the extent of the acreage affected and to a somewhat less extent the degree of damage in terms of the grain weight loss. Computer programs have been written which convert pilot surveys into forecasts of yield and which perform analyses needed for refining relationships in the forecasting procedure. Greater use has also been made of information of the fields remaining for harvest to determine acreage to be harvested.

Winter Wheat. Studies were conducted in nine States over the Winter Wheat Belt in approximately 950 fields during the 1962 crop season. Some improvements have been made in the early-season forecasting model, but additional refinements are needed to provide the desired accuracy. For the June 1 forecast, relationships involving the number of dead tillers require modification to be satisfactory for seasons in which the crop matures very early. Progress was made in formulating a second estimator to be used in forecasting the number of heads to be harvested. Improvements in the forecasting of final grain weight per head have been obtained using a spikelet count made by field samplers by graduating these field counts by counts made in a central laboratory. The number of spikelets present on very young heads is a good indicator of the final head weight at harvest. Computer programs for preparing the forecasts have been written and a pre-harvest estimate of yield for the nine-State region was made available to the Crop Reporting Board. During 1962 procedures were developed for using the survey data to estimate acreages remaining for harvest. Laboratory procedures were simplified by more efficient use of sampling techniques.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

Kelly, Bruce W. April 1962. The research program for crop and livestock estimates, 1961. Statistical Reporter, pp. 45-47.

V. NUTRITION AND CONSUMER-USE RESEARCH

Human Nutrition and Consumer and Food Economics Research Divisions, ARS

Problem. The assortment and characteristics of foods available to consumers are constantly changing with the adoption of new production, processing, and marketing practices. Constantly changing also, as nutrition science advances, is our understanding of the nutritional needs of man and the manner in which these needs can best be met by food. To help carry out the Department's responsibility to advise on the quantity and variety of foods that will assure maximum benefit and satisfaction to consumers, continuous research is essential on the nutritional requirements of persons of all age groups, and on the nutrient and other inherent values of foods and how to conserve or enhance these values in household preparations and processing. Periodic examinations of the kinds and amounts of foods consumed by different population groups and individuals also are essential for evaluation of the nutritional adequacy of diets and to give the guidance needed for effective nutrition education. Such information provides assistance needed in market analyses for different commodities and in the development and evaluation of agricultural policies relating to food production, distribution, and use.

USDA PROGRAM

The Department has a continuing program of research concerned with (1) nutritive and other consumer values of raw and processed foods as measured by chemical or physical means and by biologic response; (2) effects of household practices upon the nutritive values and inherent qualities of foods, and the development of principles and improved procedures for household food preparation, care, and preservation; (3) surveys of kinds, amounts, and costs of foods consumed by different population groups and the nutritional appraisal of diets and food supplies; and (4) development of guidance materials for nutrition education programs.

The research is carried out by two Divisions of the Agricultural Research Service--the Human Nutrition and the Consumer and Food Economics Research Divisions. Most of the work is done in Washington, D. C., and at Beltsville, Md.; some is done under cooperative or contract arrangements with State Experiment Stations, universities, medical schools, and industry. The total Federal scientific effort devoted to research in these areas totals 61.1 man-years. It is estimated that approximately 9.2 is concerned with studies related to grain products.

Human metabolic studies and the related exploratory and confirmatory studies with experimental animals and micro-organisms concerned with defining human requirements for nutrients and foods are not reported on a commodity basis, though some of the work is applicable to this report. This basic nutrition research is described on a nutrient basis in the report for the Food and Nutrition Advisory Committee. The total Federal effort is 29.5 professional man-years.

RELATED PROGRAMS OF STATE EXPERIMENT STATIONS AND INDUSTRY

State Experiment Station research in 1961 included 22.4 professional man-years devoted to studies of the inherent properties of foods and of their household use; 17.6 to analyses of a variety of foods for vitamins, various lipid and protein components, and minerals; and 2.7 to studies of food consumption and dietary levels and households and of food management practices. Although the State work has not been reported on a commodity basis, some of the above research is applicable to this report.

Industry and other organizations such as universities and professional organizations are estimated to devote about 36 man-years to research on the preparation of materials for nutrition education, surveys of diets of individuals, and studies of functional properties and stability of food and of their specific nutrient contents. Limited work is done on the amount and structure of nutrients in foods and on compiling food composition data. Again, some of this work is applicable to this report.

REPORT OF PROGRESS OF USDA AND COOPERATIVE PROGRAMS

A. Nutritive Values of Foods

1. Tables of Food Composition. Data review has been completed for a revised edition of Agriculture Handbook No. 8, "Composition of Foods... Raw, Processed, Prepared." This edition will have nearly 2,500 food items as compared with 751 items of the preceding edition, and upwards of 45,000 separate compositional values. For many foods, data will be provided for different forms--raw, cooked, canned, frozen, milled, dried, instant, dietetic, etc. The new publication will have, in addition to other constituents, data for protein, fat, carbohydrate, five vitamins (vitamin A, niacin, riboflavin, thiamine, ascorbic acid), six minerals (calcium, phosphorus, iron, sodium, potassium, magnesium). Explanatory notes for foods and nutrients will be added for users of the tables. Information on cholesterol and fatty acids will also be included.

About 435 items of grain, grain products, and their preparations will be included in the revision of Handbook 8. In addition to the major grains and flours which were listed in the previous edition, there will be new processed or prepared products including cake, pie, cooky, and roll mixes, on both the dry and prepared bases, and some frozen or chilled cakes, cookies, and pies. The list of breakfast cereals will be expanded to some 60 items including the ready-to-eat kinds and hot cereals, the latter both uncooked and cooked. Many baby foods and some soups containing grain products will also be included.

2. Vitamin Analyses. Values more representative of the vitamin B₆ content of foods now may be obtained by use of a method recently developed at Beltsville, Maryland. Separation by column chromatography of the three forms of vitamin B₆ naturally occurring in foods permit each form to be assayed individually. Values derived from these data for total vitamin B₆ approximate closely values obtained from rat bioassay.

Research is in progress to combine a number of steps in the determination of various B-vitamins in order to facilitate their simultaneous analyses, permit complete characterization of the B-vitamins in foods and to determine their overall distribution in the food supply.

The vitamin B₆ value for whole wheat flour as determined by rat bioassay was 2.9 micrograms per gram as compared to 3.5 by the microbiological assay for pyridoxine, pyridoxal and pyridoxamine. Seventy-one percent of the vitamin B₆ was found to be pyridoxine. The vitamin B₆ components of other grains and grain products are being determined microbiologically.

3. Proximate Composition. Determination of the proximate composition of foods, i.e., moisture, fat, kjeldahl nitrogen and ash, were carried out in conjunction with studies for other nutrients in foods such as the vitamins, mineral elements, fatty acids and carbohydrates. Such an arrangement added to the information on composition of foods in the various commodity groups and also permitted the calculation of nutrients on a fat free-moisture free basis or on a nitrogen or protein basis where relationships among nutrients were concerned.

Proximate composition analyses have been made on approximately 60 homemade, made-from-mix and as purchased baked goods. The items include cakes, pies, quick breads and rolls. Commercial products were usually higher in moisture and ash and lower in fat, protein and energy value than the corresponding homemade items. With few exceptions, proximate composition of dry mixes varied little among brands or over the period of time covered by the study for the same

brand of a given mix type. For most ready to bake items, moisture losses during cooking were usually between 20 and 30 percent.

B. Food Properties Related to Quality and Consumer Use

Research was conducted to ascertain whether convenience foods and added services provided by the food industry add appreciably to the cost of foods to consumers in terms of number of servings and cost per serving, savings in preparation time and content of important nutrients. A technical bulletin reporting findings for baked products is in press. The work was done at Beltsville, Maryland, in cooperation with the Economic Research Service. Commercial forms of baked products saved active preparation time and, except for some frozen products and a few mixes, saved total time for food preparation. Baked products made from commercial mixes required one-fourth to three-fourths of the active preparation time needed for homemade products.

Cakes, corn muffins and yeast rolls prepared from mixes were usually less firm than other processed or homemade forms. Baking powder biscuits, sugar cookies, pie crusts, pancakes and waffles varied considerably in tenderness among frozen, mix and homemade forms. Cookies baked from some mixes and from refrigerated, chemically-leavened dough, and pancakes and waffles made from mixes were more tender than the corresponding homemade product. The frozen form of waffles and pancakes was consistently less tender than other forms of waffles or pancakes investigated, but frozen baking powder biscuits, when baked, were equal to the homemade biscuits in tenderness.

C. Food Economics and Diet Appraisal

1. Food Consumption and Dietary Levels. Information on the nutritive value of the food consumption of households based on the 1955 survey data has been summarized in Report No. 16 of the 1955 Household Food Consumption Survey series. Average family food supplies for a week in 1955 were sufficient to provide more than the National Research Council's recommended allowances for calories and eight nutrients for which values were calculated. However, many households (48 percent) had diets that did not fully meet the allowances in one or more nutrients. Other analyses of survey data show the relation of family size, the education of the homemaker, and of income to the food consumption of households. Because of interest in information on quantities of foods used by high consumers as well as average consumers estimates were made for some 60 food items of the ninth decile--the figure dividing the highest 10 percent of the consumers from the lowest 90 percent. For flour and other cereal products the amount consumed per person in "high consumption" households was nearly twice as much as in "average consumption" households.

Two surveys were conducted cooperatively with the Marketing Research Division, Economic Research Service in Detroit, Michigan, and Fayette County, Pennsylvania, to provide evidence on the extent to which food consumption is increased and diets improved as a result of the Food Stamp Program.

A report of the food consumption and dietary levels of a group of older, low-income households in Rochester, New York, is in preparation.

Work is being undertaken on food consumption and nutritive content of diets of individuals. A systematic review and summarization of quantities of food consumed is being made through a cooperative agreement with the Minnesota Agricultural Experiment Station. A similar review of the nutritive content of the diets of individuals is being made by Washington staff.

The nutrient content of the per capita food supply, calculated each year, using data on retail weight quantities of food as developed by the Economic Research Service, provides the only source information on year-to-year changes from 1909 to date.

2. Food Management Practices. Information on the kinds, amount, and nutritive value of foods used and discarded in households has been obtained in a series of small studies. Results will help to evaluate survey data on household food consumption.

A report on household practices in handling and storing of frozen food has been prepared, based on surveys in Baltimore, Maryland, and Indianapolis, Indiana. Households provided information on the length of time frozen food was held in home storage, and the temperature of the compartment in which frozen food was being held at the time of the interview.

3. Development of Food Budgets and Other Basic Data for Food and Nutrition Programs. An important aspect of nutrition research is the interpretation and application of research findings to practical problems of food selection in relation to health. An ongoing program of work includes assembling and interpreting available information on nutritional needs, food consumption, and nutritional value of foods for use by nutritionists, teachers, health workers, and other leaders concerned with nutrition education programs.

A technical report explaining the development of the food budgets, "Family Food Plans and Food Costs," has been completed and is in press. Another in the series of popular publications on food management has been prepared, "Food for the Young Couple." A publication "Family Food Budgeting...for good meals and good nutrition," designed to help families of all sizes is also being prepared.

Regular pricing of family low-cost, moderate-cost, and liberal food plans is published in Family Economics Review on a quarterly basis for the U. S. average and on an annual basis for the regions and the low-cost food plan for the South. Each plan gives suggested quantities of food that will meet nutritional needs for each of 17 age and sex groups and for women during pregnancy and lactation so that household or population totals may be obtained.

Nutrition Committee News, a bimonthly periodical prepared for members of State nutrition committees and other workers in nutrition education provides a channel for disseminating pertinent information and for reporting nutrition education activities. A Nutrition Education Conference sponsored jointly by USDA through its Nutrition Programs Service and by the Interagency Committee on Nutrition Education was held in Washington, D. C., January 29-31, 1962.

PUBLICATIONS REPORTING RESULTS OF USDA AND COOPERATIVE RESEARCH

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